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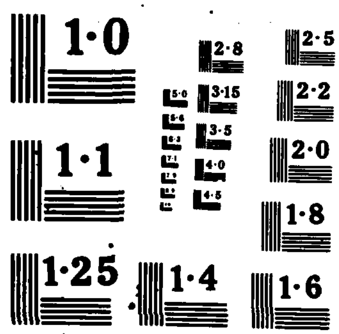

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A FIELD ARTILLERY MODULE FOR THE

AIRLAND RESEARCH MODEL

by

Leonard M. Finley

March 1986

Thesis Advisor: S. H. Parry

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A Field Artillery Module
for the
Airland Research Model

by

Leonard M. Finley III
Captain, United States Army
B.S., United States Military Academy, 1975

Submitted in partial fulfillment of the
requirements for the degree of

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Author: Leonard M. Finley III

Leonard M. Finley III

Approved by: S.H. Parry

S.H. Parry, Thesis Advisor

Robert L. Keller

R.L. Keller, Second Reader

M.G. Sovereign

M.G. Sovereign, Chairman,
Joint C3 Academic Group

D.A. Schrady

David A. Schrady,
Academic Dean

ABSTRACT

The purpose of this thesis is to establish a portion of a high resolution, prescriptive field artillery module for the Airland Research Model which, when combined with the thesis of Captain Robin Lindstrom, produces a complete, operational field artillery module. The proposed module is a hierarchical representation of field artillery relationships and consists of one element of the Division Artillery, and an artillery battalion, to include the battalion headquarters, three firing batteries and all possible fire support personnel. The module contains both planning and execution components which can operate simultaneously to simulate the conduct of current operations while planning for future operations. Command and control processes are represented as equations based on a qualitative analysis of the command and control factors involved in each decision process. Where practical, data is represented by equations to increase execution speed.

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I. THE AIRLAND RESEARCH MODEL

A. GENERAL

The Airland Research Model is being designed to conduct research on factors impacting on combat operations conducted using the Air-Land Battle doctrine. This doctrine calls for United States forces to fight an integrated battle in the air and on the ground, fighting the opposing forces in depth. Ground forces fight the battle at the forward line of troops to halt and defeat an attacking force while indirect fire and air assets fight the battle, in depth, against followon forces to defeat them before they influence the battle. Additionally, US forces must conduct operations in depth to disrupt the enemy's supply lines to prevent resupply and reconstitution of those forces already defeated.

B. REQUIREMENT FOR A NEW FIELD ARTILLERY MODEL

The purpose of this thesis is to outline the requirements necessary to create a prescriptive model of the field artillery based upon current organization, equipment and doctrine. An investigation of existing models revealed that there were none in existence that met this criteria. The STAR, CASTFOREM and FAST models employ field artillery at different levels of command; however none of these models represent the full capability of a Division Artillery equipped with TACFIRE/BCS. The methodology employed by these models requires significant user input which precludes their use in a truly prescriptive mode. Command and control modeling consists of either simplistic decision logic tables or user input actions.

The FISSTAC model developed by TRASANA is an explicit representation of the TACFIRE system but was designed to model software changes in the system and does not represent the tactical phases of a battle. Additionally, the level of detail that the model uses to represent TACFIRE communications traffic processing is prohibitive when used in the context of a model such as the Airland Research Model. Therefore, the requirement exists to develop a new model of the field artillery, drawing on existing methodology where practical.

C. ASSUMPTIONS

It is necessary to assume certain factors will remain relatively stable in order to model the field artillery. These revolve primarily around organization, major equipment and doctrine currently employed by the field artillery.

The Airland Research Model is being designed to model the battle through Corps level. Therefore, it will be assumed that the organization of the field artillery within the Corps remains relatively stable. Restructuring of the field artillery to conform to "Army of Excellence" Tables of Organization and Equipment has been accomplished. It is this basic organization, and the explicit command relationships that it outlines, which will be incorporated into the model. The module does have the capability to accept modified force structures for the purpose of experimentation, or for actual modifications, as proposed in the recently published "Azimuth of the Field Artillery" [Ref. 1].

Tactical and technical fire direction, intelligence and target generation, unit firing status and fire support coordination have been automated by TACFIRE. While the logic employed by TACFIRE is constantly undergoing revision, with revision 7 currently being fielded, no major changes to program logic are scheduled to occur. Introduction of the AFATDS system will not significantly effect the module but will require some modification to the fire direction submodules and the addition of some AFATDS routing logic.

Many tactical decisions are modeled based on the relative value of a target. A generalized value system, as explained in Ref. 2 and Ref. 3, is currently under development at the Naval Postgraduate School. This system assigns an absolute value to each target then discounts this value based on the location of the target relative to a unit's area of interest. This results in a different target value analysis (TVA) for a target depending on the level of unit by which it is considered. It is this system which will be used throughout the thesis, with the assumption that the ongoing research will result in a satisfactory target value system.

Finally, since the Airland Research Model is being designed to evaluate items using the Air-Land Battle doctrine,it is assumed that the primary emphasis will be on NATO and CENTCOM type scenarios in which conventional warfare is conducted in depth.This assumption is essential to the design of both the doctrine to be employed and the capabilities of the field artillery which are to be modeled.

D. ORGANIZATION OF THE THESIS

This thesis has been developed in conjunction with Captain Robin Lindstrom. Due to academic requirements, it has been necessary to segment the module into two theses which, when combined, provide the documentation and logic necessary to create and support an operational field artillery module. The companion thesis is listed as Reference 4 . As such, it consists of explanations of new techniques, explanations of the organization of the modules, and pseudo-code implementation of decision and allocation routines. The two theses are organized similarly with Chapters 1, 2, 3 and 6 common to both theses. Chapter 2 contains an explanation of the organization and operations of the field artillery which have been modeled. Chapter 3 presents an overview of the model and the factors represented. Chapters 4 and 5 are different as shown:

Chapter	Finley	Lindstrom
4	Target Selection	Movement
5	Target Engagement	Target Detection

Chapter 6, in both theses, contains an explanation of the database requirements for the module. Where new techniques have appeared suspect, sample programs were developed and run to demonstrate the feasibility of the methodology. These programs are included as appendices. Explanations of the submodules are contained in the chapters, by functional area, with the actual submodule logic contained in the appendices.

II. ORGANIZATION OF THE FIELD ARTILLERY

A. MISSION

The mission of the fire support system is to suppress, neutralize, delay and destroy surface targets with indirect fires and aircraft using guns, mortars, cannons, rockets, bombs and missiles [Ref. 5:p. 1-3].

B. DIVISION ARTILLERY

The division artillery is organized and equipped to provide fire support to a division. It consists of a headquarters for command, control and fire support coordination, three direct support artillery battalions and normally has one general support artillery battalion (see Fig 2.1).

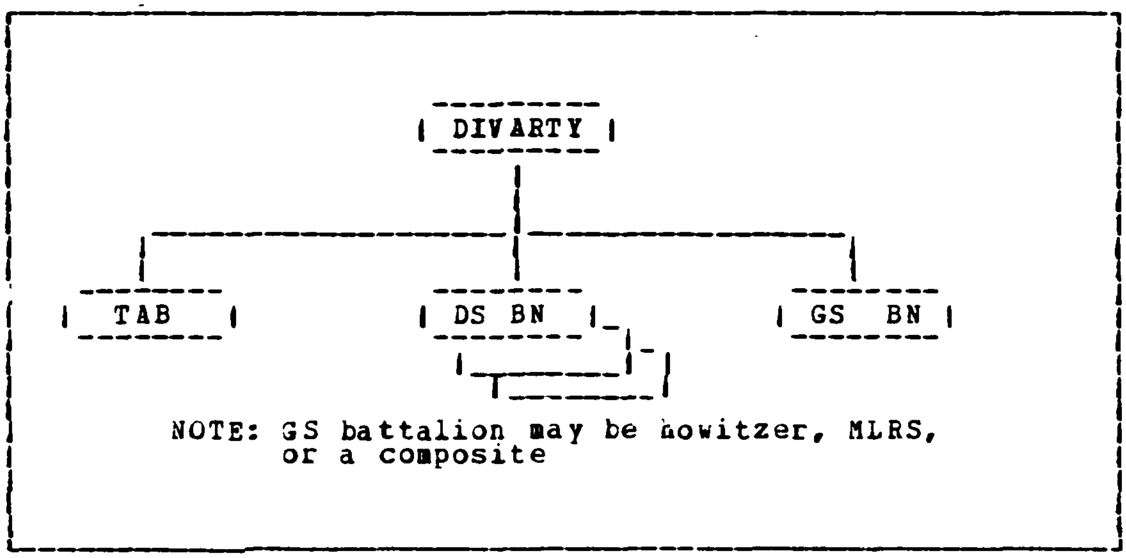


Figure 2.1 AIM Division Artillery

The division artillery headquarters establishes Fire Support Elements (FSE) at both the division main and tactical operations centers. These FSE's are responsible for integrating and coordinating the employment of all fire support assets in the division area. Additionally, these elements perform nuclear and chemical target analysis and fire planning.

C. ORGANIZATION OF FIELD ARTILLERY UNITS

Field artillery battalions are organized based on the type weapon and the mission of the unit. The main cannon systems and their employment are shown in Table 1 . The Multiple Launch Rocket System is a general support system in both divisional units and the Corps Artillery. Each battery has nine launchers which are organized into three platoons but are employed individually.

TABLE 1

FIELD ARTILLERY CANNON UNITS

TYPE WEAPON	CALIBER	HOWITZERS	MISSION
M102	105mm	6	DS
M198	155mm (T)	6,8	DS/GS
M109A2/A3	155mm (SP)	8	DS/GS
M110A2	203mm	6	GS
MLRS	203mm	9	GS

D. DIRECT SUPPORT BATTALION

The direct support (DS) battalions provide fire support to a committed maneuver element, normally brigade sized. It consists of a headquarters battery and three firing batteries (see Figure 2.2). The headquarters provides command, control and fire support coordination. Each maneuver battalion and the brigade are furnished a fire support element (FSE) to coordinate the fire support in their sector, and each company receives a fire support team to plan, integrate and request fire support in the company zone of responsibility.

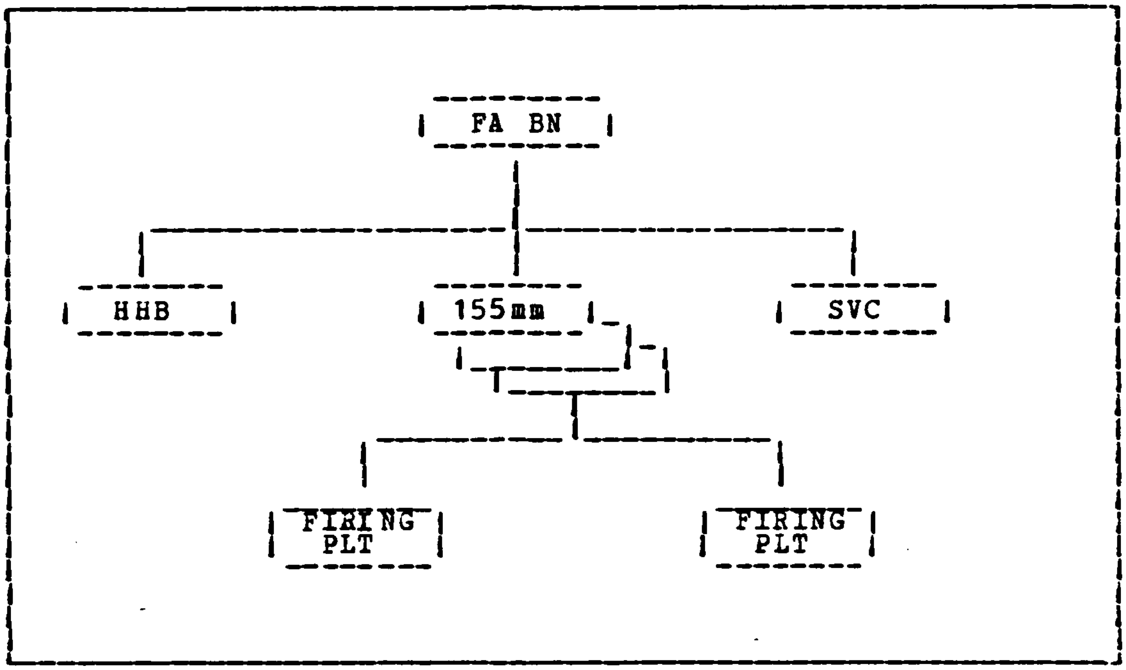


Figure 2.2 Direct Support Battalion

E. GENERAL SUPPORT BATTALION

The general support (GS) battalion provides fire support for the division and is responsive to requests for fire primarily from the division artillery. It consists of a headquarters for command and control, and either three firing batteries, or a Multiple Launch Rocket System battery and two firing batteries (see Figure 2.3).

F. TACFIRE

1. General

TACFIRE is a completely automated system for fire control encompassing all levels from Corps to firing

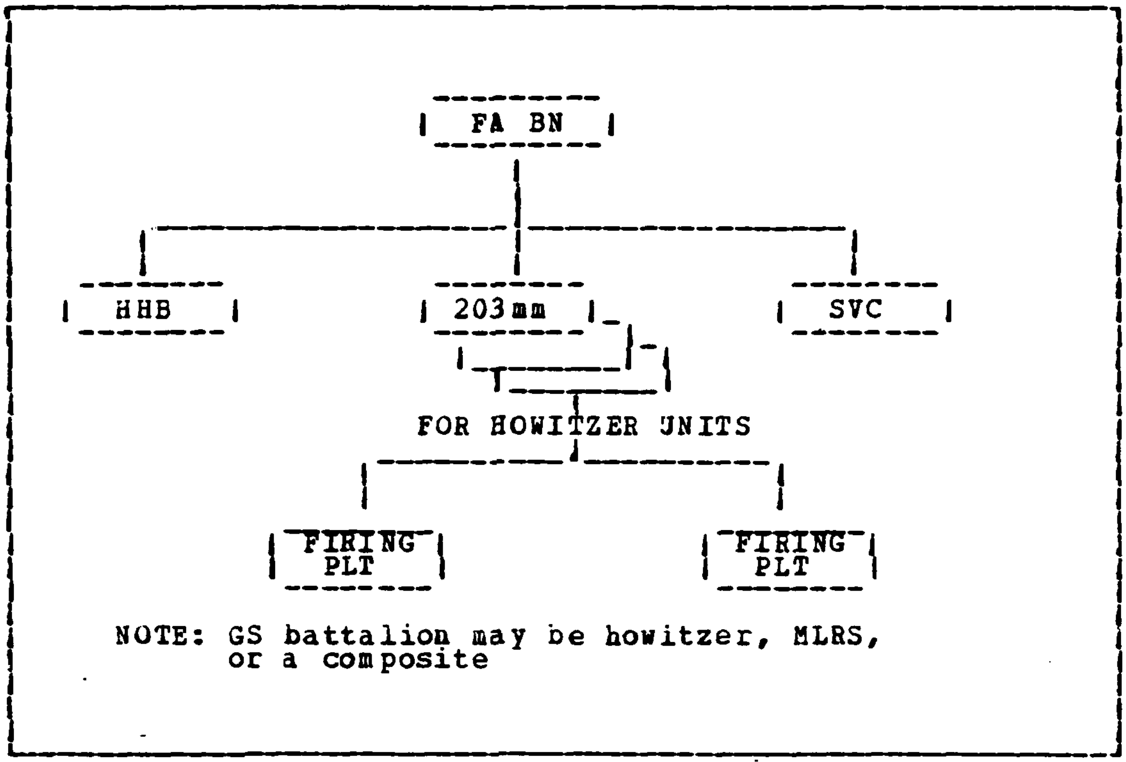


Figure 2.3 General Support Battalion

battery. Artillery units from Corps to battalion possess networked central computer systems with independent databases. Fire support elements have input/output devices which can access all levels of central computers. Additionally, all central computers can access each other and provide limited backup capability should another of the system's computers become nonoperational [Ref. 6: p. 1-1].

TACFIRE is currently deployed down to battery level in all active Army units except the 7th, 24th and 25th Divisions. Full fielding of these divisions will be accomplished by the end of FY 86. The software upgrade is continuous with version 7 currently fielded.

2. TACFIRE Software

Each level of TACFIRE possesses distinct modules with independent databases which are accessed by the other modules in the system. The modules employed in a Division Artillery are shown in Figure 2.4.

	Divarty	Battalion
Support	x	x
Artillery Fire Unit	x	x
Tactical Fire Control	x	x
Nonnuclear Fire Control	x	
Artillery Target Intelligence	x	
Fire Support Element	x	

Figure 2.4 Division Artillery TACFIRE Modules

3. TACFIRE Modules

a. Support (SPRT)

The Support module is primarily responsible for maintaining battlefield geometry and the associated fire support coordination measures which the geometry affects. It is programmed with unit zones of responsibility and fire support measures such as the FLOT, coordinated fire lines, restrictive fire lines and areas, fire support coordination lines and chemical hazard areas. Any request for fire which violates any fire support coordination measure is automatically flagged for review.

b. Artillery Fire Unit (AFU)

The AFU module stores, maintains, retrieves and transmits data on all available fire units. Data is maintained, by unit, for field artillery, tactical air support and naval gunfire with weapon, mission, zone of responsibility, ammunition status, current firing status and ammunition supply rate associated with each unit. The AFU automatically generates warnings if weapon capability or ammunition criteria is violated, and has the capability to transmit situation reports on all data stored, by unit.

c. Tactical and Technical Fire Control (TTFC)

The TTFC has the capability to automate all aspects of fire control. The program automatically analyzes each target for method of engagement in accordance with input commander criteria and the Joint Munitions Effectiveness Manual to determine the optimum method of attack for the target. It then accesses the AFU to determine which units are capable of engaging the target and selects, in a specific sequence established by the commander, the best unit(s) to fire based on unit availability. The TTFC then accesses the SPRT module to determine if fire support coordination is required and, if so, alerts the appropriate Fire Support Element (FSE). After coordination, the TTFC generates a fire order to the selected fire units.

d. Artillery Target Intelligence (ATI)

The ATI module automates many of the functions of the Division Targeting Cell. The program stores up to 1364 different targets. It analyzes each incoming target and, based on commander input, develops fire missions, alerts the unit to enemy buildups in specific locations, aggregates targets, and resolves duplication with existing intelligence. It performs counterfire targeting by correlating shell reports based on caliber and direction and generates fire missions when established thresholds are exceeded.

e. Nonnuclear Fire Plan (NNFP)

The NNFP, as currently fielded, is not operational due to the complexity of automating the decision processes involved in preparing schedules of fire. It is intended to automate the process to develop, coordinate, and disseminate schedules of fire. The program is supposed to generate a target list based on input criteria by accessing the ATI, then accessing the TTFC to determine the method of attack. The program should then determine the units to fire by accessing the AFU, and the fire support coordination requirements by accessing the SPRT. After coordination, the program logic is supposed to develop and transmit a schedule of fire to all agencies affected by the schedule.

f. Fire Support Element (FSE)

The FSE module automates many of the functions of the Division Fire Support Element. It performs conventional, nuclear and chemical target analysis, prepares nuclear fire plans and gives fallout predictions. The program accesses every Division Artillery module in the process.

4. Problems

The most significant problem that exists for modeling the TACFIRE system is the lack of programming logic for determining target priority. The system uses a three-tiered method of filing targets and a first-in, first-out queue for their processing. This creates a significant problem for modeling the Fire Direction Officer's determination of target priority, not only in the logic, but in establishing an audit trail for the prescriptive model.

G. FIRE MISSION PROCESSING

Fire missions may be originated by any element on the battlefield and will be processed in a standard manner. Assume a platoon forward observer (FO) identifies a target that he desires to engage. He relays the target location, description and recommended method of engagement to the company fire support team (FIST) chief who resolves duplication with existing requests for fire, determines the fire support agency that can engage the target most efficiently, and forwards the request to that agency. Calls for fire are transmitted to the direct support artillery battalion using the digital message device and are monitored by the battalion fire support officer (FSO). The FSO reviews the request, determines if engagement of the target will affect any other element in the battalion and, if so, coordinates the fire mission with that element. If the effects of the mission will be detrimental to the other element's mission, the FSO cancels the mission and informs the FIST chief of his decision. Additionally, the FSO determines if the mission can be more effectively engaged by the maneuver battalion's organic mortars, attack helicopters, or close air support and, if so, routes the request for fire to the selected element. This coordination is conducted simultaneously with the artillery battalion's processing of the mission and should not cause a delay in target engagement unless the safety of friendly troops becomes a factor [Ref. 5:p. k-47].

At the direct support battalion, the mission is received by the TACFIRE which plots the target and determines if it is a duplicate of an existing mission. If it is not, the target is assigned a priority based on the commander's guidance and queued for processing. When processed, the TACFIRE determines the type and amount of ammunition and the units required to engage the target, then computes firing data for those units. After review by the battalion fire direction officer, the mission is transmitted to the battery computer system (BCS) at the appropriate firing battery FDC's. This entire process is done automatically by the TACFIRE; however, any process can be overridden manually. Because of the simplistic logic to determine target priority, significant input from the battalion fire direction officer is required to determine a realistic target engagement priority.

The firing data is received at the battery FDC and queued behind existing higher priority missions. The data is sent, in turn, to the howitzer sections who prepare to fire the mission based on the ammunition type and fuze, the propelling charge, deflection (direction) and quadrant elevation. Unless otherwise specified, each howitzer section chief engages the target when his section is prepared to fire.

III. PROPOSED FIELD ARTILLERY MODEL

A. SCOPE OF THE MODEL

The proposed model addresses all aspects of a field artillery battalion except for the nuclear and chemical target planning processes. It is based on a TACFIRE equipped unit and can be modeled with any current weapon system in any configuration. The artillery battalion can be assigned any mission by establishing its entities and priority of fire. When representing the mission of direct support, the supported maneuver force can be modeled as any size but will be addressed in this thesis as a brigade.

The model consists of database, planning and execution components. The database component consists of routines and counters designed to track various entities and their attributes which are explained in Chapter 6. The planning component consists of routines to plan for future activities by evaluating and selecting future positions and routes between positions and by preparing non-nuclear target schedules. The execution component consists of routines which are responsible for conducting the current battle. The planning and execution components are designed to operate concurrently and require significant interfaces to operate properly.

B. METHODOLOGY

The field artillery module depicts the hierarchical organization of the field artillery battalion to include its relationship to the division artillery headquarters and to the supported units from brigade level through company. It consists of routines which model the major activities the field artillery battalion must accomplish. These routines contain several small subroutines, each of which performs a single function, and contains logic and programs which allow the system to plan and execute fire support while interacting with the supported maneuver forces at all levels. This modularity allows the establishment of an audit trail and facilitates any future changes which may be required. Additionally, normal operations and specified thresholds cause the module to link to the communications, logistics, movement and transportation modules. Variable resolution architecture has been designed to facilitate aggregation up to the firing battery level or disaggregation to the individual section level.

The methodology used in creating the field artillery module is a combination of the use of TACFIRE logic and the creation of doctrine- based, dynamic logic represented in functional form. TACFIRE modeling is based on logic flows from the technical manual [Ref. 7], and actual program code. Logic flows and strings have been simplified and technical fire direction has been eliminated. The logic used to determine asset assignment to targets and target engagement priority has been augmented by decision submodules to represent the functions of a maneuver battalion fire support officer and the artillery battalion fire direction officer.

Target engagement priority at the battalion fire direction center is determined by a target value weighting scheme as explained in Chapter 4. A target is assigned a numerical value based upon the establishment of a generalized weighting scheme as discussed in reference 2 . This value is based on the target's capabilities and location relative to the supported unit's area of interest and its queue category. Queues have been established to represent the five major categories of fire support missions (countermaneuver, counteracquisition, counterfire, command control and communications, suppression of enemy air defense) and an adjustment factor based on a normal distribution factor is applied to the target value based upon current firing priorities to produce an adjusted target value. This adjusted value is then processed based on the type mission (immediate, planned or unplanned).

Field artillery doctrine has been used as the basis for the development of the command and control decision making processes used in the module. These decision processes are represented as equations intended to portray the factors and tradeoffs involved in a decision and are updated to reflect current status based on previous operations (see Chapter 4, Ref. 4). Fire support team and fire support officer functions have been modeled in an attempt to portray the full capabilities of these elements and to allow an audit trail to be established. The forward observer is capable of making complex decisions to include the ability to adjust any type mission and to control the time of opening fire as an 'at my command' or a 'time on target' mission. The fire support officer allocates indirect fire assets, performs fire support coordination and serves as the maneuver unit's conduit to the intelligence aggregated in the TACFIRE system.

Tabular data requirements have been analyzed and, where possible, are represented as a functional form which closely approximates the data. This should significantly decrease the computational time required by the model. An explantion of the methodology used to create the functional forms is in Chapter 6.

C. FACTORS CONSIDERED IN THE MODEL

1. Personnel

Howitzer crews and both battalion and battery fire direction center crews are modeled by section. A minimum operating level is established, below which the section is ineffective. Other personnel are aggregated at the battery level. Fire support sections are explicitly modeled with the exception that platoon forward observers are aggregated with the platoon leader for the purposes of attrition.

2. <u>Intelligence</u>

The Division Artillery Target Intelligence computer is modeled to allow for automatic generation of targets based on commander input parameters. It receives input from, and allows access to, all field artillery agencies in the model except for the Fire Support Team. This capability is not fully utilized in the model but has been designed to provide the database and outputs necessary for the future creation of nuclear and chemical target planning modules.

3. <u>Operations</u>

a. Tactics

Batteries can be employed as either a complete unit or by platoon which are treated as separate entities. Movement is by entity based on an immediate action status dictated by battalion. Battalion controls all movement of the units based on fire support requirements and the anticipated threat through either the immediate action status or a movement order.

b. Fire direction

Fire missions are processed through two submodules. First, the mission goes through TACFIRE based logic to determine the method of attack then through a decision matrix submodule to determine its priority. The model is designed to use TACFIRE variables to facilitate the use of existing operation plans as model data input. Fire mission processing, reporting, module interfaces and information exchange is automatic and uses the program logic flow of the TACFIRE system.

c. Fire support coordination

Fire support coordination requirements are modeled after the TACFIRE system's capabilities and are resolved by the appropriate agency. Additionally, fire support officers provide situation reports, request schedules of fire and report changes to the direct support battalion. Fire support officers have access to the Division Artillery Target Intelligence unit to generate data for the supported unit.

4. Fire Support Teams and Target Acquisition Sensors

Fire support teams are modeled down to platoon forward observer level. Fire support team (FIST) chiefs will perform fire support coordination within their company sector. Additionally, the capabilities of various target acquisition sensors may be represented by modifying the attributes of the FIST. This allows the modeling of all current and projected acquisition assets such as radar and elevated target acquisition sensors (ETAS).

5. Logistics

Limited logistics are incorporated in the model with only ammunition and operational availability of key equipment represented. Data can be maintained at varying levels from individual vehicle to firing battery in the Artillery Firing Unit submodule which can be accessed from the battalion level.

Ammunition will be based on the unit's basic load vehicle configuration with either a controlled or available supply rate (ASR/CSR) assigned. While resupply is not incorporated into the model, the module does produce ammunition and fuel requirements which can be used to interface with the logistics module. Until this is created, a percentage of the ASR/CSR should be credited periodically to the unit based on user input. At the highest level of resolution, rounds expended during firing are charged to the ammunition carrier which is resupplied from the battery ammunition section during movement. In accordance with field artillery doctrine, the ammunition on the howitzer is the last to be fired. Loss of any vehicle is also a loss of the ammunition on board.

6. Maintenance

Operational readiness of all major equipment is not explicitly modeled however, equipment status can be represented by distribution functions using the mean time between failures (MTBF). The methodology for this representation is currently under development by Captain Olsen in a thesis which should be published in March, 1986.

All of the factors explained above are designed in a hierarchical structure. This structure allows the artillery to be modeled as any type unit from individual howitzer sections to firing batteries by establishing the attributes of the units to be employed and disconnecting the submodules not required for the selected level of resolution.

D. DECISION LOGIC

An analysis of the representation of command and control processes in current combat simulations reveals that they do not provide the detail required to form the basis for a prescriptive model. The processes are represented by either simplistic decision tables or are user input. Decision tables simply react to an established threshold without analyzing the factors involved in the decision process and are relatively static for the duration of the simulation. User input makes a predetermined decision. Neither of these methods provides qualitative or quantitative data on the individual factors and tradeoffs involved in any single decision process, much less provides for an analysis of the synergistic effects of these factors.

In an attempt to solve this shortcoming, the representation of command and control processes in the field artillery module has been designed to make tactical decisions while providing the facts required to develop the database necessary for the simulation of more complex tactical decisions. The methodology employed is three-phased:

(1) Based on doctrine, individual tactical decisions have been identified, together with the factors involved in each decision and the tradeoffs considered in reaching the decision.

(2) The factors and tradeoffs contained in each decision were expanded to create a detailed, qualitative description of each decision process.

(3) A quantitative analysis of each descriptor and tradeoff was developed that represented its nature. This curve was then approximated by a known distribution. The functional representation of the decision process was then applied to the module.

The specific logic for each submodule is contained in the appropriate chapter for that module. Because of the lack of an established database from which to draw, many of the factors are based on intuition and assumptions which must be validated during the running of the model. For instances where the methodology appeared questionable, computer simulations were created using the algorithms. These simulations are contained in the appendices.

IV. OVERVIEW OF MODULE LOGIC

1. FO Target Selection

A. This logic (Routine FO.GENERATE) receives a target list from Routine FO.GENERATE and determines the relative value of the targets to the artillery based on the expected maneuver unit's engagement of the targets.

B. The user establishes the priority of engagement for each target type by all of his assets and the maximum engagement capability of each asset.

1. FO Target selection Logic

a. Given the FO's detected list as follows:

TGTMSNNO	LOC	CAT	TVA	TYPE	FIRESTATE	FORG	SPEED
1000	xy	CM	300	Tank Plt	NO	2500	10
1001	ab	C3	2000	Regt HQ	NO	4000	0
1002	cd	CF	1000	152mm FA	NO	5000	0
1003	ef	SEA	500	ADA site	NO	2000	0

b. Given the following user established direct fire priorities and current asset status:

TARGET TYPE	ASSETS				
	TANK	APC	TOW	M60	DRAGON
ADA	3	1	2	4	5
ARMOR	2	3	1	5	4
FA	1	2	4	3	5
HQ	2	1	3	5	4

ASSET TYPE	ASSET STATUS		
	NUMSYS	ENGAGETVA	TVACOMMIT
TANKS	10	100	500
APC	10	50	500
M60	10	10	100
DRAGON	6	30	180
TOW	3	50	125

C. The FO discounts the value of each target based on its location relative to the maneuver unit's area of interest:

*TGTVALUE = TVA * DISCOUNT FACTOR where*

*DISCOUNT FACTOR = exp<-disc*RG>*

TGTVALUE = the value to the FO of engaging the target

TVA = the generalized value of the target

DISC = the unit discount factor of the target based on its range (RG) from the maneuver unit as explained in ref above

D. The FO determines the adjusted target value (TGTTVA) based on the expected engagement:

For assets priority 1-n:
  TVALEFT=NUMSYS*ENGTVA-TVACOMMIT
  For target priority 1-n
    TGTTVA=TGTVAL-TVALEFT
  Next target
Next asset

where:

TVALEFT is the engagement value potential of an asset given the asset is available

NUMSYS is the number of a type asset available in the unit position

ENGTVA is the full engagement capability of each asset of a particular type

TVACOMMIT is the aggregated

c. Given a unit discount factor of 0.2 for all targets:

TGTMSNNO	TGTVALUE
1001	899
1002	365
1003	335

d. Computation of the adjusted target value to the FO would be:

(1) TGTMSNNO 1001 and 1002 are beyond direct fire range and therefore their TGTTVA is equal to their TVA

(2) TGTMSNNO 1000 and 1003 are considered in order of their TVA

Asset	PRI TGT	TVA Left	Adjusted Target Value
APC	1003	500-500=0	1003- 335-0= 335 1000- 182-0= 182
TOW	1000	150-125=25	1000- 182-25= 157 1003- 335
TANK	1000	1000-600=400 1000-757=243	1000- 157-157= 0 1003- 335-243= 92
M60	1003	100-100=0	1000- 0 1003- 92

amount of engagment capability of assets of a given type which is currently commited

E. Targets are processed, in priority, through engagement criteria to the FSO (Routine FSO.ALLOCATE) for selection of the best asset to engage the target

e. The FO's target list is processed, in priority, to the FSO (Routine FSO.ALLOCATE) and would be:

TGTMSNNO	TGTTVA
1001	899
1002	368
1003	92

Target 1000 would be engaged by direct fire and is therefore purged from the FO's list

2. FO Target Engagement Criteria

For targets of value to artillery units, this logic determines the best method of engagement by computing whether the location error and movement rate of the target can be covered by a battery sheaf. The logic determines:

A. Whether the expected error in location of the target, given the FO type (TGTMSNNO.LOCCONF), is less than a battery sheaf (MAXTGTDIST). If so, the method of fire is fire for effect (TGTMSNNO.CTL=FFE).

If TGTMSNNO.LOCCONF<MAXTGTDIST, TGTMSNNO.CTL=FFE

2. FO target engagement criteria

TGTMSNNO	OBS	SPEED	.MOVE(1)	.LOCCONF(2)	.CTL
1001	DF	0	STA	100	FFE
1002	RADAR	0	STA	50	FFE
1003	FO	0	STA	300	FFE
(1000)	FO	10	STA	300	FFE

(1) For TGT 1000:
(10km/hr)*(1hr)/(60min)*(2min)=330
MAXTGTDIST=400 (8 howitzers*50meters/howitzer)
therefore TGTMSNNO.CTL = FFE

B. Whether the movement distance of the target, given the expected response time, (AVEBNMSNTIME) is less than a battery sheaf. If so, the method of fire is fire for effect.

If TGTMSNNO.SPEED/AVEBNMSNTIME < MAXTGTDIST, TGTMSNNO.CTL=FFE

C. In both cases, if the equation is false, the method of control is adjust (TGTMSNNO.CTL=ADJ).

3. FSO Asset Allocation

A. This logic (Routine FSO.ALLOCATE) accepts targets as input from FO's and, using asset response data and threat capabilities, determines the utility of employing each asset against each target. It then selects the best asset to attack each target.

B. The FSO maintains the status of each asset and its average response time during the current operation. The user inputs the probability of kill for each asset-target pair, and the probability of loss for each air asset by each threat air defense system. The tactics routine (BNTAC.THRESH) described in ref 4 determines the probability of loss for the artillery based on unit actions to date.

3. FSO asset allocation

a. Because Routine FSO.ALLOCATE receives input from at least three FO's, assume that the active targets are as follows:

TGTMSNNO	LOC	CAT	TVA	TYPE	FIRESTATE	FORG	SPEED
1000	xy	CM	300	Tank Plt	NO	2500	10
1001	ab	C3	2000	Regt HQ	NO	4000	0
1002	cd	CF	1000	152mm FA	NO	5000	0
1003	ef	SEA	500	ADA site	NO	2000	0

b. The assets available to the FSO and their values are:

ASSET	E(RESPONE TIME) ON STATION	E(RESPONE TIME) NOT ON STATION	PK EQN TK	PK EQN ADA	PK EQN RCT	P(LOSS) EQN SA8	P(LOSS) EQN SA9	P(LOSS) EQN ZSU	P(LOSS) EQN SA7
ATTK HELO	.0833	.500	0.6	0.6	0.6	.16	.12	.17	.07
CAS	.0833	1.00	0.6	0.7	0.7	.12	.09	.12	.03
MORTAR	.0333		0.2	0.2	0.2	P(det)=0.18			
FIELD ARTY	.0333		0.3	0.3	0.3	P(det)=0.08			

with asset values of:
Field artillery (FA)-600 Mortar (MTR)-400
Close air support (CAS)-2000 Helicopter (AH)-1500

C. The utility of employing each asset is computed as follows:

E(GAIN)=(TVATGT*PKTGT)
-(TVAASSET*PLOSS.ASSET)
U(X)=E(GAIN)*Pr(AVAILABLE)
where:

EGAIN is the expected gain of employing the asset
TVATGT is the target's value
PKTGT is the probability that the asset can kill the target
TVAASSET is the value of the asset
PLOSS.ASSET is the probability that the asset will be lost as a result of engaging the target
U(X) is the utility of employing the asset against the target
Pr(AVAILABLE) is the probability that the asset can engage the target prior to the target reaching its full combat potential

D. Targets are then forwarded to the appropriate asset for engagement. Artillery targets are forwarded to the FDC (Routine TTFC.FIREMISSION) for engagement.

c. The utility of employing assets against the targets would be:

ASSET	1000	1001	1002	1003
FA	43.6(1)	753(4)	352(1)	204(2)
MTR	>0	369(5)	128(6)	119(4)
CASOS	>0	1160(1)	310(1)	219(1)
CASSCR	>0	1160(1)	310(1)	87(6)
AHOS	>0	1065(2)	260(2)	140(3)
AHSCR	>0	1065(2)	260(2)	109(5)

NOTES: (1) The numbers in parentheses indicate the order in which assets would be selected, given that they are available.

(2) Targets are forwarded to the appropriate element for prosecution (Routine TTFC.FIREMISSION for FA).

4. FDC Tactical Fire Direction

A. This logic (Routine TTFC.FIREMISSION) receives targets from all sources and processes them in accordance with user established priorities. It determines the method of engagement, type and quantity of ammunition to fire, and selects the fire unit(s) to engage the target.

B. Targets are grouped into five categories (table 18). Using the area under a normal distribution curve as a surrogate, the user establishes a modification value (as multiples of sigma) for each category of target given that every possible category is designated as priority (PRICAT).

C. The area under the curve (ADJVAL) is computed using an approximation of the standard normal curve from ref 8 as shown in Appendix F.

4. FDC tactical fire direction

a. The FDC receives targets from three FSO's (Routine FSO.ALLOCATE) and from the Division Artillery ATI (Routine ATI.MFR) and therefore the target's received by the FDC are given to be:

TGTMSNNO	LOC	CAT	TVA	TYPE	.CTL
1000	xy	CM	300	Tank Plt	ADJ
1001	ab	CJ	2000	Regt HQ	FFE
1002	cd	CF	1000	152mm FA	FFE
1003	ef	SEA	500	ADA site	FFE

b. Given the following user established target value modification for each category, given the current priority category:

WHEN PRICAT IS	AREA UNDER THE CURVE IS COMPUTED BY						
	MEAN	SIGMA	CM	CA	CF	SEAD	CJ
CM	0	1	6	3	4	1	6
CA	0	1	4	6	1	1	4
CF	0	1	1	4	6	1	4
SEAD	0	1	1	4	1	6	4
CJ	0	1	3	4	2	3	6

c. The value of the targets will be multiplied by the appropriate value of ADJVAL. This value is approximated by the equations shown in Subroutine TTFC.FIREMISSION.TGTPRIORITY which is in Appendix F. The ADJVAL's computed for the priority scheme given in (b) above are:

D. Adjusted target values (TGTMSNNO.VALUE) are computed by multiplying the target value (TGTMSNNO.TVA) by the appropriate adjustment factor (ADJVAL), given the category of the target (TGTMSNNO.CAT) and the current priority category of targets (PRICAT) as follows:

For TGTMSNNO. 1000-n
TGTMSNNO.VALUE=TGTMSNNO.VALUE *ADJVAL

			ADJVAL		
PRICAT	CM	CA	CF	SEAD	C3
CM	1.0	.72	.95	.34	1.0
CA	.95	1.0	.34	.34	.95
CF	.34	.95	1.0	.34	.95
SEAD	.34	.95	.34	1.0	.95
C3	.72	.95	.68	.72	.95

d. This would result in the adjusted target values for the fire direction center as shown:

		ADJVAL VALUE WHEN PRICAT IS				
TGTMSNNO	TVA	CM	CA	CF	SEAD	C3
1000	300	300	210	285	102	300
1001	2000	1440	1900	1360	1440	2000
1002	1000	340	950	340	1000	950
1003	500	170	475	170	500	475

Given a priority category of countermanuever (CM), the targets would be processed as follows:

TGTMSNNO. 1001-1002-1000-1003

E. Ammunition selection is determined by:

(1) Entering table 18 with the target type (TGTMSNNO.TYPE) to determine the method of attack

(2) Entering table 19 with target type (TGTMSNNO.TYPE), activity (TGTMSNNO.ACT) and size (TGTMSNNO.SIZE) to determine the two preferred munitions (TGTMSNNO.AMMO1 and TGTMSNNO.AMMO2)

(3) Entering the Joint Munitions Effectiveness Manual with the method of attack, target type and the two preferred munitions to determine, for each munition, the number of volleys to be fired (TGTMSNNO.NUMVOL1 and TGTMSNNO.NUMVOL2)

e. Target-ammunition selection would be:

TGTMSNNO	TYPE	MOA (1) Tbl 18	AMMO BLOCK Tbl 19	SELECTED 155mm AMMO Tbl 19	NUMBER OF VOLLEYS (2)
1000	Tank Plt	E	8	CUHD DPICM	4 rounds BTRY 4
1001	Regt HQ	E	1	DPICM HE	BN 3 BN 5
1002	152mm FA	E	3	DPICM HE	BTRY 3 BN 5
1003	ADA site	E	4a	DPICM HE	BTRY 3 BN 3

NOTES:

(1) MOA = method of engagement (v=volley, e=effects)

(2) The number of volleys required is taken from the classified JMEMS and the numbers in the table are for demonstration only

F. Fire unit selection attempts to use the the minimum number of units capable of accomplishing the mission as follows:

(1) Fire unit priority is based on the least number of active

f. Fire unit selection is based on the following status:

	NUMBER OF MISSIONS NOW	1000	1001	1002	1003	NUMBER OF ROUNDS CUHD	DPICM	HE
A	2	3	4	5		10	198	612
B	4	5			6	2	112	438
C	1	2				0	43	564

missions in the fire unit queue with selection logic:

For fire unit prioirty 1-n,

-Can any single unit accomplish the mission with either munition?

-Can any two units accomplish the mission with either munition?

-Can the entire battalion accomplish the mission with either munition?

(2)When the answer to any of the above questions is yes, the logic ends with the selection of that unit(s). If the answer to all three questions is no, the mission is ended and a request for additional fire is forwarded to the Division Artillery.

(3)For selected units, the target data is sent to the appropriate FDC(s) for engagement (Routine BTRY.FIRE).

The priority of firing units is B-C-A and the selection is as follows:

Can the target be engaged by		1001	1002	1000	1004
#1	AMMO1 AMMO2	NO NO	NO NO	NO NO	NO NO
#2	AMMO1 AMMO2	NO NO	*YES* (A)	*YES* (A)	*YES* (B)
#3	AMMO1 AMMO2	NO NO			
#1 & #2	AMMO1 AMMO2	NO			
#1 & #3	AMMO1 AMMO2	NO NO			
#2 & #3	AMMO1 AMMO2	NO NO			
BN	AMMO1 AMMO2	*YES* (BN)			

and the missions would be assigned as follows:

TGTMSNNO	UNIT	AMMO
1001	BN	BN, 3 volleys, DPICM
1002	A	BTRY, 3 volleys, DPICM
1000	A	4 rounds, CUHD
1003	B	BTRY, 3 volleys, DPICM

5. Battery Target Engagement

A. This logic simulates the actions at the fire unit to prepare for a mission (Routine BTRY.FIRE) and to conduct the firing (Routine BTRY.SHOOT) on a target.

B. Targets are filed in the battery queue in accordance with their adjusted value and are processed when the fire unit is capable of handling an additional mission. When processed, the logic determines:

(1) Whether the unit is capable of firing.

(2) The time to schedule firing (TGTMSNNO.FIRE) based on user input howitzer reaction time (HRT).

TGTMSNNO.FIRE=current DTG + HRT

5. Battery Target Engagement

a. Given that the platoon firing staus for Battery A is yes (PLTSTATUS=YES) for the entire engagement sequence. The battery has fired the two missions that were in the queue in paragraph 5 above and has received the missions desinated above. The battery queue and computations are:

TGTMSNNO	ADJVAL	CTL	AMMO	NUMVOL	COMPUTATIONS FU.NRG	CHG	TOF	ERROR RG	DF
1001	1440	FFE	DPICM	3	6000	5	21.1	16	4
1002	1000	FFE	DPICM	3	8000	5	24.8	18	5
1000	300	FFE	DPICM	4	4000	5	10.8	14	2

b. Given the current clock time is 1200.0. The user input howitzer reaction time (HRT) of 45 seconds and the reload time is 30 seconds, the actions would be scheduled as follows:

TGTMSNNO	VOLLEY#	FIRED	IMPACT
1001	1	1200:45	1201:06.1
	2	1201:15	1201:36.1
	3	1201:45	1202:06.1
1002	1	1202:30	1202:54.8
	2	1203:00	1203:24.8
	3	1203:30	1203:54.8
1003	1	1204:15	1204:28.7

(3)The time of flight of the projectile (TGTMSNNO.TOF), firing errors and the trajectory of the rounds.

(4)The time to schedule the impact of the rounds (TGTMSNNO.IMPACT).

C.At the time of firing, the FO is notified (Routine FO.FIREMISSION) of the time of impact in order to evaluate the effects of firing.

6.FO Evaluation of Firing

This logic (Routine FO.FIREMISSION) determines whether the FO is capable of observing the impact and, if so, the results of firing (TGTMSNNO.EFF). If the FO is not capable of observing the impact, the effects are unknown (TGTMSNNO.EFF=UNK). The effects of firing are determined by the percentage of targets in the array affected by the firing (PEREFF):

PEREFF=(# targets effected)/(# targets in array)

For PEREFF=	TGTMSNNO.EFF=
>.30	DEST
.10<P<.30	NEUT
<.10	SUPP

6. FO evaluation of effects of firing

a.Given that the FO is capable of observing the targets listed in paragraph 6 above and the evaluation of target effects shown below. The FO's calculations would be:

TGTMSNNO	TARGETS # AFFECTED	TARGETS # IN ARRAY	PEREFF	.EFF	.CTL
1001	10	50	.20	NEUT	EOM
1002	no Line of sight		unk	UNK	EOM
1003	3	3	1.0	DEST	EOM

Given the evaluation of firing above, the FO sends an end of mission to the battery (Routine BATTERY.FIRE) which purges the target from its file and, if capable, begins the engagement process on the next mission in its queue (paragraph 6 above).

The end of mission is then passed to the battalion FDC (Routine TTFC.FIRE MISSION) which forwards the mission data to the Division ATI and, if capable, processes the next mission in its queue (paragraph 5 above).

The FO decrements his mission counter and, if capable, pops a mission from his queue which is passed to the FO target selection logic (Routine FO. GENERATE) to determine target engagement methods (paragraph 1 above).

V. TARGET SELECTION

A. GENERAL

This chapter describes the modeling of the target selection process, from the time that a target is acquired or generated, until the target is forwarded to the appropriate element for engagement. The actual logic for the routines is contained in Appendix E. Modeling considerations are applied to targets in two broad categories.

1. Observed Fire Targets

These are targets, normally acquired by physical or electronic observation, on which the engagement of the target will be observed by that physical or electronic element.

2. Unobserved Fire Targets

These are targets, normally aggregated or deduced from intelligence data, on which the engagement of the target will not be observed.

The logic flow for the routines described in this chapter is shown in Figure 5.1 .

B. OBSERVED FIRE TARGETS

1. Observer Decision Logic

a. General

This section describes the selection logic for observed fire targets. This logic, which is modeled in two stages, applies only to the Field Artillery module. First, the observer must select targets from his detected list which he desires to be engaged and forward these targets to the Fire Support Officer (FSO). The FSO must then determine the asset which can most effectively engage the target and forward the request for fire to that element.

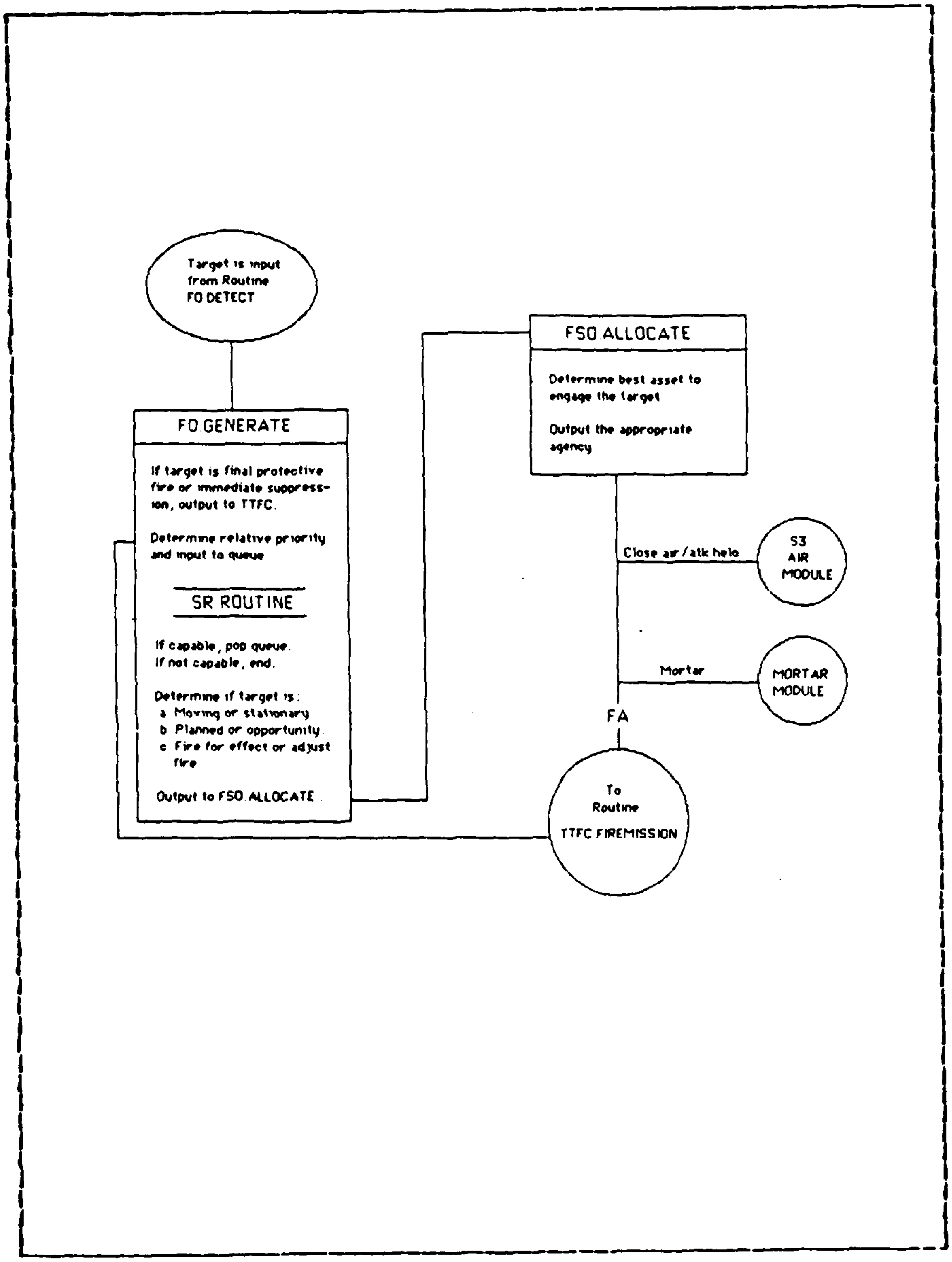


Figure 5.1 Target Selection Routines Logic Flow

b. FO Engagement of a Given Target

This logic determines the priority of engagement for targets which the forward observer has detected. The program determines whether the target is expected to be within direct fire range when the engagement by the field artillery should occur. If so, the program accounts for direct fire priorities in computing the target value. For targets outside direct fire range, the program discounts their value based on their location relative to the maneuver company's area of influence.

(1) <u>Algorithm</u>.

For direct fire range:
TGTVALUE = TVA - ENGTVA of maneuver assets

For indirect fire range:
TGTVALUE = TVA * DISCOUNT FACTOR where
DISCOUNT FACTOR = exp<-disc*RG>

TGTVALUE = the value to the FO of engaging the target

TVA = the generalized value of the target

DISC = the unit discount factor of the target based on its range (RG) from the maneuver unit as explained in Ref. 2

(2) <u>Factors</u>. <u>ENGTVA of maneuver units</u> -The user must establish the priority of assets to be employed on each target type and the total expected TVA that an asset can engage in a given time period (see Table 2). The target type for an array is the type target with the largest aggregated value in the array.

This table is normally established by the user in conjunction with the maneuver module and, at the highest level of resolution, contains data by individual weapon system. For each type target, the user establishes the priority of engagement of the target by ranking his assets 1-n. The maximum simultaneous engagement capability of each individual asset is then established. At lower levels of resolution, the data would reflect the asset-target priorities and engagement capabilities of the smallest maneuver unit represented in the model.

Based on the current activities of the maneuver elements, the FO can determine what portion of the target is expected to be engaged by direct fire assets and discounts the target value. An example of this methodology is shown in Figure 5.2 . This figure demonstrates that, for the given type target (armor), the priority of engagement is:

TOW - Tank - APC - Dragon - M60

and the engagement capability of the assets are:

TOW	3*50 = 150
Tank	10*100 = 1000
APC	10*50 = 500
Dragon	6*30 = 180
M60	10*10 = 60

Given their current status, the target value is adjusted as shown in the figure.

Discount factor -The user must establish the discount factor (disc) based on the target's location relative to the supported unit's area of influence. The value of targets outside of direct fire range are discounted by this factor as described in Ref 2 .

The FO must have a table to track the activities of the maneuver elements as shown in Table 3 . A similar table is normally established in conjunction with the maneuver module in order to determine the status of direct fire systems. Targets with an assigned value are stored in the FO queue and, when capable, the FO processes them in accordance with their value to the FSO for engagement.

TABLE 2

FO TARGET-ASSET PRIORITY

TARGET TYPE (1)	ASSET PRIORITY/ENGTVA (2)				
	TANK	APC	TOW	M60	DRAGON
ADA					
ARMOR					
ARTY					
MORTAR					
ROCKET/					
VEH					
GUN					
ASSY AREA					
BUILDING					
BRIDGE					
CENTER					
PERSONNEL					
SUPPLY					
TERRAIN					
ENGAGETVA					

NOTES:
(1) The target type designated for an array is the type target with the largest aggregated combat power
(2) The assets are ranked in priority 1-n for each target type
(3) See figure 5.2 for an explanation of the use of this data.

TABLE 3

MANEUVER ELEMENT STATUS

ASSET TYPE	ASSET STATUS		
	NUMSYS (1)	ENGAGTVA (2)	TVACOMMIT (3)
TANKS			
APC			
M60			
DRAGON			
TOW			
***			
***			

NOTES:
(1) NUMSYS is the number of a particular type system currently available in the position
(2) ENGAGTVA is the amount of TVA that each type system can engage
(3) TVACOMMIT is the total amount of TVA which the type system is currently engaging
(4) See figure 5.2 for an explanation of the use of this data.

2. Fire Support Team Submodule

a. General

This submodule is responsible for generating targets to include identification, location and method of engagement, to be prosecuted by a variety of fire support assets. The submodule can represent a wide variety of forward observer attributes ranging from a human platoon forward observer (FO) to a target acquisition radar, and is capable of simulating the conduct of engagements by the FO, a remotely piloted vehicle (RPV), aerial-platformed observer, or weapons-locating radar system. Additionally, capabilities of the forward observer element possessing special attributes or specialized equipment, both currently available or projected, can be represented.

Given a target array in which the largest aggregated type target is an armor system with total array value of 500. User established priorities are given as:

TARGET TYPE	TANK	APC	TOW	M60	DRAGON
ADA	3	1	2	5	4
ARMOR	2	3	1	5	4

and two current asset status are shown. The status in the TVACOMMIT column in parentheses is used in the second example shown below:

ASSET TYPE	ASSET STATUS		
	NUMSYS	ENGAGETVA	TVACOMMIT
TANKS	10	100	500 (850)
APC	10	50	500 (500)
M60	10	10	100 (60)
DRAGON	6	30	180 (180)
TOW	3	50	125 (100)

The computation would be performed as follows:

<u>Asset</u>	<u>TVA Remaining</u>	<u>Adjusted Target Value</u>
TOW	3*50 - 125 = 25	500-25=475
Tank	10*100 - 500 = 500	475-500= -25

Since the target value is less than zero, the target would not be engaged by indirect fire

****

If the asset status was as shown in parentheses, the computations would be:

<u>Asset</u>	<u>TVA Remaining</u>	<u>Adjusted Target Value</u>
TOW	3*50 - 100 = 50	500-50=450
Tank	10*100 - 850 = 150	475-150= 325
APC	10*50 - 500 = 0	325-0=325
Dragon	6*30 - 180 = 0	325-0=325
M60	10*10 - 60 = 40	325-25=300

The target would be filed in the FO queue with an adjusted value of 300.

Figure 5.2 Computations of FO Target Selection

The submodule also performs fire support coordination for targets within its company zone of responsibility which have been generated by another element.

b. Database

The submodule requires a table to establish the attributes of the type observer to be represented. Because the representation of the attributes is dependent on the acquisition methodology, this table is not included but should contain the representation of:

(1) FO range.

(2) Visibility footprint.

(3) Visibility degradation factors.

(4) Simultaneous acquisition capabilities.

c. User Input

The user must input the capabilities of the FO system to be represented and the characteristics of the artillery systems to be employed. A list of the input data is shown in Table 17 ,Appendix E.

d. Internal Inputs and Accesses

The primary input to this submodule comes from the scheduler which activates the target acquisition logic. After processing acquisitions, the submodule outputs the target data to the FSO submodule. A list of variable exchanges is shown in Table 4 .

e. Routines

Routine FO.DETECT is activated each time period by the scheduler. The logic for this routine has not been developed due to a lack of definitive guidance on the nature of the operational model. The routine should be designed to acquire targets and pass control to Routine FO.GENERATE.

Routine FO.GENERATE evaluates targets and determines the method of engagement. It receives target acquisitions from Routine FO.DETECT and, for final protective fires and immediate suppression missions, passes control to

TABLE 4

FO VARIABLE EXCHANGE

Routine	Call By	Call to	Variable
FO.DETECT	SCHEDULER		Activates the logic
FO.GENERATE	FO.DETECT		TGTMSNNO. and data
		TTFC. FIREMISSION	TGTMSNNO.CTL= FPF
		FSO.ALLOCATE	TGTMSNNO.
FC.FIRE MISSION	BTRYSHOOT		TGTMSNNO.EFF= SHOT TGTMSNNO.CTL= AMC BTRY READY flag
		BTRYFIRE	TGTMSNNO.= nnnnCORR, nnnnFFE
		BTRYSHOOT	TGTMSNNO.CTL= FIRE
		FO.END	TGTMSNNO.CTL= EOM
FC.END	FO.FIREMISSION		TGTMSNNO.CTL= EOM
		BTRYFIRE	TGTMSNNO.CTL= EOM
FC.COORD	MVR CDR MODULE		FO.nSTATUS

Routine TTFC.FIREMISSION. Other missions are processed to Subroutine FO.GENERATE.PRIORITY which determines the priority of engagement for targets outside direct fire range and then places them in the FO queue. Targets inside direct fire range are passed to Subroutine FO.GENERATE.DFPRI to determine their priority, and are then filed. When processed from the queue, control is passed to Subroutine FO.GENERATE.START. This subroutine uses target permanence and possible target location error to determine the method of control. Fire for effect missions are output to Routine FSO.ALLOCATE, and adjust missions are output to Subroutine FO.GENERATE.ADJ. Subroutine FO.GENERATE.ADJ determines whether the target should be engaged as a fire for effect "at my command" mission, or as an adjust fire mission then transfers control to Routine FSO.ALLOCATE.

Routine FO.FIREMISSION processes ongoing missions from the first round fired until the mission is ended. It receives input from Routine BTRYSHOOT indicating that a round has been fired. Based on the method of control of the mission, control is passed to Subroutine FO.FIREMISSION.EFF, FO.FIREMISSION.AMC or FO.FIREMISSION.ADJ. Subroutine FO.FIREMISSION.ADJ determines the correction to an adjustment and, if warranted, changes the method of control to fire for effect. Control is then passed to Routine BTRYFIRE. Subroutine FO.FIREMISSION.AMC controls the firing of "at my command missions" then passes control to Subroutine FO.FIREMISSION.EFF which evaluates the effects of firing and passes control to Routine FO.END.

Routine FO.END processes completed fire missions. It receives input from either Routine TTFC.FIREMISSION or Routine FO.FIREMISSION indicating that a mission has been completed. The routine updates the FO data, outputs the mission data to Routine BTRYFIRE, then either passes control to Routine FO.GENERATE to begin processing another mission from the queue or terminates.

Routine FC.COORD performs fire support coordination in the FO's zone of responsibilty. The routine receives input from Routine TTFC.FIREMISSION indicating the requirement to fire a mission in the company zone that has been initiated by another element. The routine insures that the target exists and that firing will not adversely effect the supported company, then outputs the coordination status to Routine BTRYSHOOT.

3. <u>FSO Asset Allocation to a Given Target</u>

a. General

This logic is designed to simulate the decision of which asset should be selected to engage a given target with minimum expenditure of friendly assets at this instant of the battle. The assets normally considered include mortar (mtr), field artillery (FA), attack helicopters (AH) and close air support (CAS).

b. Algorithm

E(GAIN) = (TVATGT*PKTGT)-(TVAASSET*PLOSS.ASSET)

U(X) = E(GAIN)*Pr(AVAILABLE) where:

EGAIN is the expected gain of employing the asset

TVATGT is the target's value

PKTGT is the probability that the asset can kill the target

TVAASSET is the value of the asset

PLOSS.ASSET is the probability that the asset will be lost as a result of engaging the target

U(X) is the utility of employing the asset against the target

Pr(AVAILABLE) is the probability that the asset can engage the target prior to the target reaching its full combat potential

c. Factors

(1) Time Criticality of Engagement. Certain missions such as immediate suppression and suppression of enemy air defenses are so time critical that the expected response time, E(Tr), is the only factor to consider. Becuase of this, these type missions bypass the logic and are forwarded directly to the artillery.

(2) Type and Size of Target vs. User Input. The user may, for operational reasons or a specific study, specify either certain assets against a specific target type or the level of one of the factors that must be met in asset selection. In either instance, this guidance becomes the overriding factor.

(3) Expected Gain, E(gain), from Engagement. This factor assumes that all elements included in the simulation have a relative value for both current and future time. The E(GAIN) is computed to determine the value of applying the asset to the target and, if less than zero, the algorithm must account for the risk status of the commander.

(4) Probability of Loss of an Asset. This factor is based on the primary threat to the asset. The Pr(loss) for mortar and field artillery is the perceived Pr(detect by counterfire radar|a volley is fired) and the Pr(loss) for attack helicopter and close air support is the Pr(kill by the most effective ADA asset in the target area).

(5) Probability of kill of an asset against the target type. This factor is determined from the data provided by the Army Material Systems Analysis Activity (AMSAA).

(6) Availability of the Asset. This perceived factor is the ability of the asset to engage the target before the target reaches its full combat potential. It is based on the performance of the system in the battle to date, given its current status, and is expressed as the

percentage of travel time of the target to the FLOT until engaged. The computation of this factor may require some modification upon the completion of the thesis on determination of target value by Cpt Kilmer which should be published in March, 1986. The initial value of this factor is user input and, after utilizing the given asset, is based on the average response time for the asset during the battle and its present status. For example, CAS has two E(Tr)'s depending on whether aircraft are on station or must be scrambled, and the routine maintains flags to indicate the status of the elements. The E(TR) for field artillery and mortars are their average mission times.

E(TR) = E(TGT TIME TO FLOT)/AVE RESPONSE
TIME OF THE ASSET
IF E(TR)>1, E(TR) = 1

The data for these factors can be maintained as a single table which is updated after each move (see Table 5). This allows the decision logic to be periodically maintained and, therefore, decisions are made based on the actual performance of the assets and current intelligence.

d. Test of the Methodology

In order to test the methodology in Routine FSO.ALLCCATE, a computer simulation was conducted which is at Appendix H. Arbitrary target values were assigned to five targets and four assets. Using data for four different Soviet ADA systems derived from unclassified sources (which were verified as reasonable against classified data), the simulation was conducted for each target defended by each ADA weapon, at three different speeds for ranges 5, 10 and 20 kilometers.The simulation performed in a reasonable fashion, making selections for the target/asset pair and the defense of the target which, based on experience, appear

TABLE 5

FSO ASSET DATA

<table>
<tr><th rowspan="2">ASSET</th><th colspan="2">E (RESPONSE TIME)</th><th rowspan="2">Pk EQN</th><th rowspan="2">P (LOSS) EQN</th></tr>
<tr><th>ON STATION</th><th>NOT ON STATION</th></tr>
<tr><td>ATTK HELO</td><td>Average divert time</td><td>Average scramble time</td><td rowspan="2">PHYSICS</td><td>P (Loss of system|ADA defenses)</td></tr>
<tr><td>CAS</td><td>Average divert time</td><td>Average scramble time</td><td>P (Loss of system |ADA defenses)</td></tr>
<tr><td>MORTAR</td><td colspan="2">Average mission time</td><td rowspan="2">EQUATION</td><td>P (Detect| one volley)</td></tr>
<tr><td>FIELD ARTILLERY</td><td colspan="2">Average mission time</td><td>P (Detect| one volley)</td></tr>
</table>

logical (see Table 6). The most effective, and generally highest value assets, were selected to attack the highest value targets until the threat to the asset became prohibitive. At this point, a less effective, and therefore lower value asset was selected.

As a result of the test of the methodology, the logic appears feasible. It accounts for target and asset value, target defenses, range from the FLOT and asset responsiveness. As such, the methodology will be incorporated to Routine FSO.ALLOCATE to determine asset selection and as a feeder to the target value module algorithm.

4. <u>Fire Support Officer Submodule</u>

a. General

The FSO submodule is responsible for selecting assets to engage targets in order to provide timely and effective fire support. It uses input from the FIST and SPRT submodules in order to determine target engagement resources

TABLE 6

ASSET SELECTION FOR SPECIFIED TARGETS

The table below shows the asset selection, in priority given by the simulation. The target is listed along with its value a brief explanation of the asset selected given the target defenses is provided.

TARGET	VALUE	SELECTION GIVEN DEFENSE
ADASITE	500	At 5km, for a stationary target-AH,CAS,FA All others-FA
REGTHQ	2000	CAS-OS,AH-OS,FA At 20km, CAS-SCR also selected
TKPLT	300	5km, given defenses of SA8/ZSU:FA SA7/SA9:AH-OS,CAS-OS,FA >5km, given defenses of SA7:AH-OS,CAS-OS,FA All others:FA
BMPPLT	250	FA, except when defended by SA7:AH-OS
INFPLT	50	5km: MORTAR >5km: Do not engage

CAS-OS = close air support, on station
CAS-SCR = close air support, scrambled
AH-OS = attack helicopter, on station
AH-SCR = attack helicopter, scrambled
FA = field artillery
MTR = mortar

and availability. Additionally, the submodule accesses the Non-Nuclear Fire Planning (NNPF) submodule to initiate a schedule of fires based on user input parameters. The submodule is also an interface between the manever commander and his fire support agency, providing control and coordination for the artillery assets, and a channel for communications flow of situation updates between the maneuver units and the field artillery units.

b. Database

The FSO maitains a status of possible assets as shown in Table 5 .

c. User Input

The user must input the expected response times for the assets available to the FSO. These times are used in the selection of assets only until the asset is used, at which time the actual response time replaces this factor.

d. Internal Inputs and Accesses

The FSO submodule receives fire requests from the FO submodule, selects assets, and outputs the data to the appropriate module (TTFC if field artillery is selected). It also receives data from the field artillery for the maneuver unit and maneuver information for the artillery. The variable exchanges are shown in Table 7 .

e. Routines

Routine FSO.ALLOCATE receives either data on targets to be engaged from Routine FO.GENERATE, or update data from maneuver elements on the status of assets available for target engagement. For target requests, the routine computes the expected gain from employing each available asset against the target, given the target defenses, and selects the highest gain as the optimum asset. The target data is then output to the appropriate routine for that asset (Routine TTFC.FIREMISSION for field artillery). If an air asset is selected, control is passed to Subroutine FSO.ALLCCATE.AIR which prepares a SEAD group of targets to be fired in conjunction with the air attack. For update data, the routine passes control to Subroutine FSO.ALLOCATE.UPDATE which updates the asset table and terminates.

Routine FSO.INTEL is the conduit for the field artillery and maneuver unit to pass information. The routine receives target buildup data from Routine ATI.MFR and passes

TABLE 7

FSO VARIABLE EXCHANGE

Routine	Call By	Call to	Variable
FSO. ALLOCATE	S3 AIR MODULE		TGTMNSNO.EFF TGTMSNNO. STATUS
	SCHEDULER		FSO.nSTATUS
		TTFC. FIREMISSION	TGTMSNNO.
		MTR MODULE	TGTMSNNO.
		S3AIR MODULE	TGTMSNNO.
FSO.INTEL	SPRT.COORD		TGTMSNNO.CTL
	MVR S3 MODULE		NNFP.nTYPE .CAT .CTL

control to the maneuver intelligence routine. It also receives requests for non-nuclear fire plans (NNFP) from the maneuver operations routine which it passes to Routine SPRT.PREFP to initiate the nonnuclear fire planning process.

C. UNOBSERVED FIRE TARGETS

1. General

This section describes the modeling of the selection of targets for engagement with unobserved fire. These targets are not detected but rather are aggregated or deduced from intelligence data by the Artillery Target Intelligence submodule as described in Ref. 4 . Selection of the targets is modeled in two categories, nonnuclear fire plans and targets of opportunity. Targets of opportunity are addressed in Chapter 5, Ref. 4 .

2. Nonnuclear Fire Plan Logic

This logic is designed to develop schedules of fire and groups of targets for engagement. The logic closely parallels the current artillery doctrine for fire planning as shown below:

PHASE	PRIMARY TARGETS	TGTMSNNO.CAT
I	Hostile FA	CF
II	Reserves,C2	C2
III	Forward elements	CA,SEAD
IV	Maneuver elements	CM

NOTE: The target mission categories are shown in Appendix D

The program divides targets into groups in accordance with their category (TGTMSNNO.CAT) to develop blocks of targets. Within each block, targets are scheduled by their permanence codes (TGTMSNNO.TP) with the most permanent target scheduled first. These codes are explained in Chapter 5, Ref. 4 and are standard TACFIRE variables which indicate the mobility of targets, relative to each other. The targets are scheduled to be engaged by all designated fire units simultaneously. After all targets are scheduled, the program attempts to reschedule targets which are engaged by a single fire unit into an open block of time for that unit. The program then transmits the appropraite portions of the fire plan to the corresponding fire units for engagement at the designated time.

3. Battalion Nonnuclear Fire Plan Submodule

a. General

The battalion Nonnuclear Fire Plan (NNFP) prepares schedules of fire in accordance with requests from a fire support officer. The submodule can develop preparations, counterpreparations, counterfire schedules and groups of targets. The submodule receives a target list which is scheduled for firing based on the permanence of the targets and the required time of fire. Groups of targets are scheduled for simultaneous engagement.

b. Database

There is no separate database required for this submodule however, it does use the target permanence codes in the TTFC database in preparing the schedule.

c. User Input

The user must specify the limitations on target permanence and age to be used by the ATI in developing the target list. Additionally, the user input criteria to the TTFC is applied to targets during the fire plan routine. A list of the input is shown in Table 19 .

d. Internal Input and Accesses

The NNFP receives the target list from the TTFC submodule which initiates the fire planning process. The NNFP then outputs the scheduled fire missions to the Battery Fire submodule. A list of variable exchanges is shown in Table 8 .

e. Routines

Routine NNFP.PREFP prepares fire plans for engagement by the fire units. It receives a target list from Routine TTFC.FIREMISSION which contains the targets to fire, the fire units to engage each target and the method of fire for the fire units. The routine then determines the sequence

TABLE 8

NNFP VARIABLE EXCHANGE

Routine	Call By	Call to	Variable
NNFP.PREFP	TTFC.FIRE MISSION		Target list with: TGTMSNNO. .LOC .FU's .AMMO .NUMVOL .FIRETIME .TP .CAT
		BTRYSHOOT	TGTMSNNO. .AMMO .NUMVOL .TOT

and time to fire for each mission and outputs this data to Routine BTRYSHOOT.

VI. TARGET ENGAGEMENT

A. GENERAL

This chapter describes the modeling of the engagement of targets by the artillery regardless of their nature or source. It explains the battalion tactical fire direction and the firing battery actions required to model the engagement of targets. Battery technical fire direction is not explicitly modeled. The logic flow between the routines described in this chapter is shown in Figure 6.1 with the actual routine logic contained in Appendix F.

B. BATTALION FIRE DIRECTION

1. Battalion Fire Direction Decision Logic

a. General

This logic determines the priority of engagement for targets in the fire direction center (FDC) queue. The logic modifies the value of the targets based on a user input factor and the current priority of fire dictated by the maneuver force. The program uses the area under a normal curve, whose mean and standard deviation are specified by the user, to modify the TVA of the target. The selection of a normal distribution is not based on any mathematical theory but is used as a surrogate for the current method of designating a target value for each type target given the current priority of fire.

b. Determination of Target Priority

To cause a target category to be prosecuted, a normal probability distribution (area under the curve) probability is applied to the target's inherent value from its TVA evaluation. This probability is used as a weighting factor in order to scale the target's situational worth. This worth is established, by category, relative to the

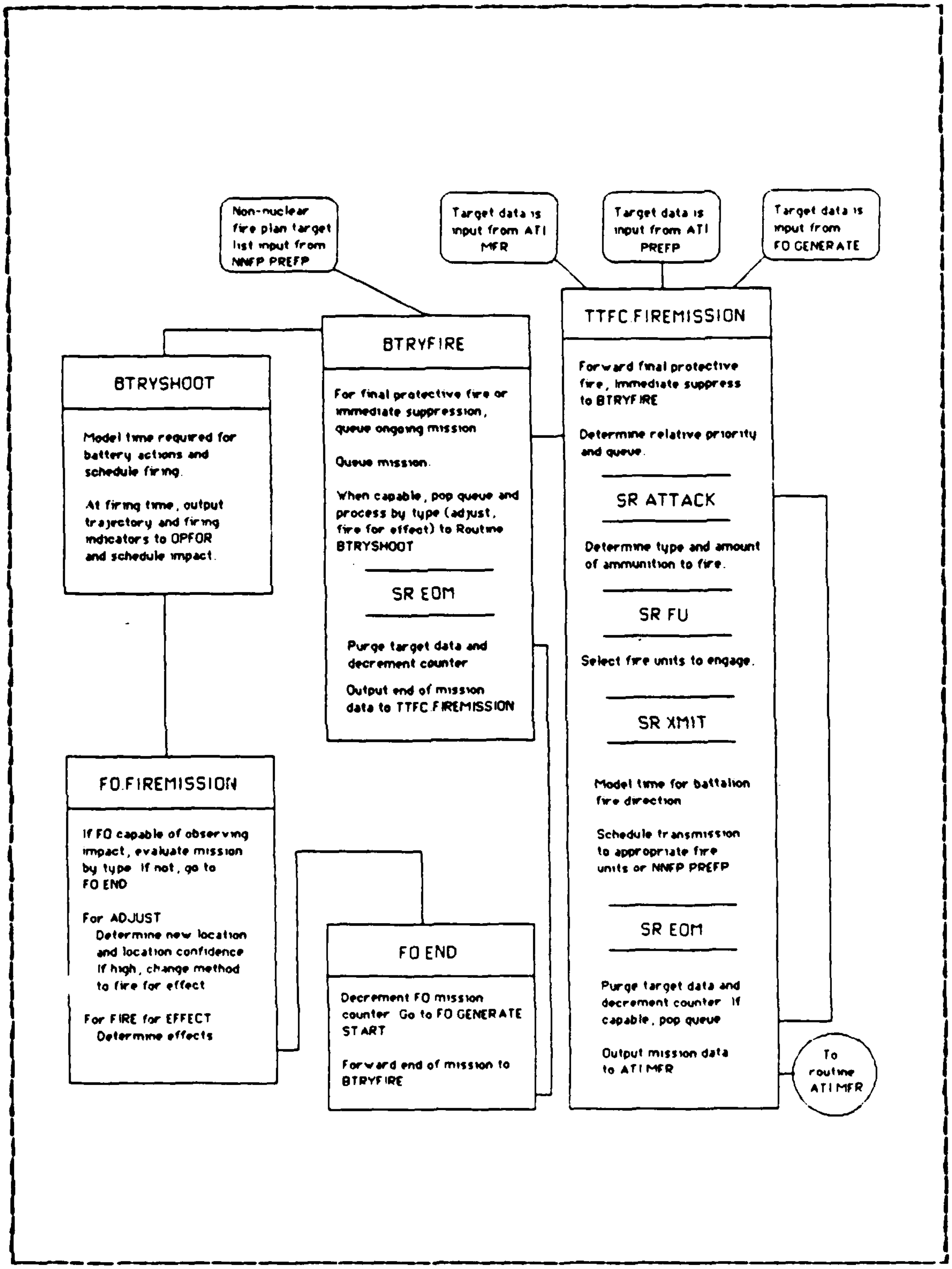


Figure 6.1 Target Engagement Routines Logic Flow

supported maneuver unit's operational priorities. The user input required is shown in Table 9 and includes, for each category of target, the amount of area under the curve (specified as a multiple of sigma) to be applied to every other category of target. For example, should the user establish a standard normal distribution, N(0,1), target values would be multiplied as follows:

Number of std dev	Adjustment factor
0	0
2	0.68
4	0.95

The target types and their designated categories are shown in Table 15 and an example of the methodology is contained in paragraph (3) below.

(1) Execution. A routine has been developed to determine a closed form solution for the area under a normal curve using the polyncmial approximation of Normal probabilities. This approximation is taken from Ref. 8. The weighting factors are the n-standard deviation area under the normal curve probabilities determined by a specified normal distribution, where n is a user specified value, generally an integer value.

(2) Algorithm.

For PRICAT and TGTMSNNO.CAT,
TGTMSNNO.VALUE = TGTMSNNO.TVA * ADJVAL where:

PRICAT = the current priority category of target
TGTMSNNO.CAT = the category of the target
TGTMSNNO.VALUE = the relative value of the target given the current priority of fire
TGTMSNNO.TVA = the generalized value of the target
ADJVAL = the approximation of the area under the normal curve

TABLE 9

TARGET VALUE MODIFICATION

WHEN PRICAT IS	AREA UNDER THE CURVE IS COMPUTED BY						
	CURVE		NUMBER OF SIGMA USED				
	MEAN	SIGMA	CM	CA	CF	SEAD	C3
CM	0	1	6	3	4	1	6
CA	0	1					
CF	0	1					
SEAD	0	1					
C3	0	1	3	4	2	3	6

NOTE: The values contained in the table are for use with the example of the methodology.

(3) <u>Example of Methodology</u>. Given the user established target value modification for each category as shown in Table 9 and any current priority category, the value of the targets will be multiplied by the appropriate value of ADJVAL. This value is approximated by the equations shown in Subroutine TTFC.FIREMISSION.TGTPRIORITY which is in Appendix F.The ADJVAL's computed for the priority scheme given in (1) above are:

			ADJVAL		
PRICAT	CM	CA	CF	SEAD	C3
CM	1.00	0.72	0.95	0.34	0.51
C3	0.72	0.95	0.68	0.72	1.00

This would result in the adjusted target values for the fire direction center as shown below. Sequence of engagement is shown in parentheses.

			VALUE WHEN PRICAT IS	
TGT	CAT	VALUE	CM	C3
Tank	CM	100	100(5)	73(5)
Radar	CA	400	290(3)	380(3)
FA	CF	500	475(1)	340(4)
ZSU 23	SEAD	600	204(4)	435(2)
REGT HQ	C3	1000	408(2)	1000(1)

NOTE: The values assigned to the targets are for demonstration and do not reflect the model's target value system.

The current priority category of target is input to the subroutine by the maneuver command module. Based on this category, target values are modified by the normal distribution factor and an adjusted target value is computed. Targets are then filed in the FDC queue and processed, when the FDC is capable, in accordance with this adjusted target value.

2. Battalion Tactical and Technical Fire Control Submodule

a. General

The Battalion Tactical and Technical Fire Control (TTFC) submodule conducts tactical fire direction. It plots targets, determines coordination requirements, determines the units to fire, the volume and type ammunition to fire, and the method of attack. It also determines the queue and priority of the target then generates the fire order to the firing elements. The TTFC receives an end of mission from the battery firing submodule which it uses to update its mission list.

b. Database

The TTFC requires an Attack Methods Table to model the TACFIRE munitions selection logic. This table is a derivation of data from the Joint Munitions Effects Manual (JMEMS) and contains the type and number of rounds to be fired based on the target type, degree of protection and user input. The table is not included because it is howitzer dependent and is readily available in the database of many other simulations and in classified TACFIRE publications.

c. User Input

The user can input data to override many of the parameters stored in the database. These variables are in the TACFIRE format but are abbreviated to eliminate parameters not used by the model. Additionally, the times to conduct fire direction and the maximum number of simultaneous missions must be input. A list of the required input is shown at Table 22 .

d. Internal Input and Accesses

The submodule receives fire missions from various sources and transmits the method of engagement to the appropriate battery firing submodules. Before transmission of a fire order, the TTFC must receive confirmation of fire support coordination from either the SPRT or the appropriate FSO submodule. During the conduct of the mission, the TTFC will receive notification from any firing unit which is assigned a mission that it cannot accomplish.Upon conclusion of the mission, it receives an end of mission from the AFU, updates the mission list, computes the new battalion average mission time and forwards the report to the ATI submodule.

During normal operations the TTFC may be accessed by the Nonnuclear Fire Plan submodule to determine data for schedules of fire which that submodule is preparing. A list of variable exchanges is shown in Table 10 .

e. Routines

Routine TTFC.FIREMISSION receives its initial input from either Routine ATI.MFR or Routine FSO.ALLOCATE for a fire mission, or from Routine ATI.PREFP for a schedule of fire. The routine ensures that the mission is not a duplicate of an existing mission, then passes control to Subroutine TTFC.FIREMISSION.TGTPRI to determine the priority of the target. Final protective fires (FPF) and immediate suppression (IS) are output immediately to Routine BTRYFIRE. Other missions are queued and processed, in priority, according to the battalion's simultaneous mission processing capability.

When the FDC is capable of processing missions, control is passed to Subroutine TTFC.FIREMISSION.ATTACK to determine whether the target should be engaged as an effects or volley target, and the top two priority munitions for engagement. It then determines, for the top priority munitions, the number of rounds of each to be fired. For FASCAM requests, control is passed to Subroutine TTFC.FIREMISSION.FASCAM to determine whether the requestor has the authority to employ the munitions. If so, control is passed to Subroutine TTFC.FIREMISSION.FU and, if not, the mission is ended. For all other munitions, control is passed to Subroutine TTFC.FIREMISSION.FU which selects available fire units to engage the target based on their firing status.

After unit selection, the subroutine determines the number and type of rounds to be fired by each unit on the target and passes control to Subroutine TTFC.FIREMISSION.XMIT. This subroutine ensures that the

TABLE 10

TTFC VARIABLE EXCHANGE

Routine	Call By	Call to	Variable
TTFCFIRE MISSION	ATI.MFR		TGTMSNNO. .CTL=FFE =EOM
	BTRY.SHOOT or BTRY.FIRE		TGTMSNNO. .EFF=NOFIRE .CTL=ECM
	ATI.PREFP		TGTMSNNO. .CTL=NNFPn
	FSO.ALLOCATE		TGTMSNNO. .LOC .TYPE .SIZE .CTL .DOP .FSCOORD .PRI .SPEED .RG
		FC.END	TGTMSNNO. .EFF=EOM
		BTRY.FIRE	TGTMSNNO .PRI .NUMVOL1 .AMMO1 .NUMVOL2 .AMMO2 .CCORD .CTL FU.NRG
		NNFP.PREFP	Same as BTRY FIRE but: .CTL=NNFPn
		ATI.MFR	TGTMSNNO. .EFF .DTG
		SPRT.COORD	TGTMSNNO. .LOC .FSCOORD

mission is coordinated, determines the time required to process the request, and schedules the output to either Routine NNFP.PREP for schedules, or to Routine BTRYFIRE for normal fire missions. At the scheduled time of transmission, the routine decrements the battalion mission counter and determines whether the battalion can process another mission. If so, the routine pops the queue and passes control to Subroutine TTFC.FIREMISSION.ATTACK. If the battalion is incapable of processing another mission or the queue is empty, the routine ends.

In some instances, missions are processed to fire units that subsequently become incapable of prosecuting the mission. In these instances, the routine will receive input from Routine BTRYSHOOT. Control is then passed to Subroutine TTFC.FIREMISSION.MFR which augments the time wasted counter and transfers control to Subroutine TTFC.FIREMISSION.FU. At this point, mission processing resumes as described above.

End of mission reports are received from Routine BTRYFIRE and control is passed to Subroutine TTFC.FIRE MISSION.MFR. This subroutine updates battalion mission processing times, computes a new average battalion mission time and passes control to ROUTINE ATI.MFR.

C. BATTERY FIRE DIRECTION

1. <u>Battery Fire Direction Decision Logic</u>

There is no decision logic associated with the battery fire direction submodule as only those actions required to fire a round are modeled. Technical fire direction is not explicitly modeled; however, data required by the model from the Tabular Firing Tables are included. A methodology for representing this tabular data in functional form is described in Chapter 6.

2. <u>Battery Firing Submodule</u>

a. General

The Battery Firing submodule models the actions at the fire unit upon receipt of a fire order from the battalion FDC. The fire unit receives and evaluates the mission priority and fires any final protective fire or immediate suppression immediately. Other missions are placed in the unit queue by priority.

b. Database

The submodule requires the equations to model the errors inherent in the firing system and the equations to model the time of flight and trajectory of projectiles (see Table 14). The methodology used to create the equations is shown for a M109A2 howitzer in Chapter 6 of this thesis. If, for the purpose of a particular study, the exact data is required, the tabular data for the appropriate weapons can be input.

c. User Input

The user must input the mean and standard deviation for various actions in the fire unit and the maximum time that a mission can remain active before requiring validation (see Table 23).

d. Internal Inputs and Accesses

The submodule is activated by the receipt of a fire order from the battalion TIFC. It accesses the battery AFU to insure that the unit is capable of firing a mission prior to executing any mission. If the mission is an adjust fire or FO controlled mission, the submodule will receive adjustment data or the order to fire respectively, from the FO submodule. Before each round, the submodule determines the time of flight of the projectile and forwards this data to both the FIST and battle damage assessment submodules. At the conclusion of the mission, the submodule receives an end of mission from the FO, updates its files and forwards the data to the AFU and TIFC (see Table 11).

TABLE 11

BTRYFIRE VARIABLE EXCHANGE

Routine	Call By	Call to	Variable
BTRY.FIRE	TTFC.FIRE MISSION		TGTMSNNO. .PRI .AMMO1 .AMMO2 .NUMVOL1 .NUMVOL2 .COORD .CTL FU.NRG
	FO.FIRE MISSION		TGTMSNNO. .nnnnCORR .nnnnFFE TGTMSNNO. .CTL=EOM
	FO.END		TGTMSNNO. .CTL=EOM
		TTFC.FIREMSN	TGTMSNNO. .EFFECTS= NOFIRE
		BTRY.SHOOT through the scheduler	.TOF .LOC .IMPACTLOC
BTRY.SHOOT	BTRY.FIRE through the scheduler		TGTMSNNO. .TOF .LOC .IMPACTLOC
	FO.FIRE MISSION		TGTMSNNO .CTL=EOM
		BDA MODULE	IMPACTLOC
		OPFOR MODULE	Flash, sound smoke and trajectory indicators

TABLE 11
BTRYFIRE VARIABLE EXCHANGE (continued)

	AFU.AMMO UPDATE	For how 1-n .AMMO.N .NUMRDS
	TTFC.FIREMSN	TGTMSNNO. .EFFECTS= NOFIRE
	FO.FIRE MISSION	TGTMSNNO. .EFF=SHOT or BTRYREADY if CTL = AMC

e. Routines

Routine BTRYFIRE models the actions of the fire unit upon receipt of a fire mission. The routine receives input from Routine TTFC.FIREMISSION to initiate a mission and from Routine FO.ADJ for subsequent corrections to an existing mission. Final protective fires and immediate suppression missions preempt existing missions and are fired immediately. Subsequent corrections are passed to either Subroutine BTRYFIRE.ADJ or to Subroutine BTRYFIRE.FFE based on the type mission. Other missions are queued until the fire unit is available. When processed from the queue, the routine perfoms checks to ensure that the fire unit is capable of processing the mission and has the specified munitions. If not, the unit ends the mission and passes control to Routine TTFC.FIREMISSION. If capable, control is passed to either Subroutine BTRYFIRE.ADJ for adjust missions or to Subroutine BTRYFIRE.FFE for fire for effect missions. These subroutines are identical except for their ammunition requirements and determine the time of flight, firing errors and corresponding impact location, trajectory and time required to prepare to fire. At the specified time to fire, control is passed to Routine BTRYSHOOT.

End of mission is input from Routine FO.FIREMISSION and control is passed to Subroutine BTRYFIRE.EOM which updates the unit status and determines whether the unit can engage another target. If so, the subroutine pops the queue and passes control to either Subroutine BTRYFIRE.ADJ or to Subroutine BTRYFIRE.FFE. The subroutine also outputs the end of mission data to Routine TTFC.FIRE MISSION.

Routine BTRYSHOOT models the actions at the fire unit at the time of firing and is activated by the scheduler from Routine BTRYFIRE. The routine ensures that the unit is capable of firing before the firing is allowed to occur, determines the impact time and outputs the mission to all appropriate modules. The routine then augments the volleys counter, computes the ammunition expended and outputs this data to Routine AFU.AMMOUPDATE.

VII. INTERNAL MODULE DATABASE

A. GENERAL

This chapter describes the modeling of the database requirements for the field artillery module. The submodules described below maintain the battlefield geometry, unit attributes and status, and contain a methodology for representing tabular firing data in functional form. They access, and are accessed by, nearly every routine in the module as shown in Figure 7.1 .The actual logic for these routines is contained in Appendix G.

B. BATTALION SUPPORT SUBMODULE

1. General

The Battalion Support Submodule (SPRT) is a file containing battlefield geometry and is used primarily for fire support coordination. It represents the zones of all maneuver units down to company level based on their assigned arcs, and associates forward observers and fire support officers with these areas. Requests for fire from a source will be compared with the known fire support coordinator and, if they are not the same, coordination with that person will be initiated.

2. Database

There is no requirement for any database other than user input to be established.

3. User Input

The user must input data to establish the unit boundaries and associate fire support personnel with these zones. This input is not in the TACFIRE format (see Table 24 and Figure 7.2).

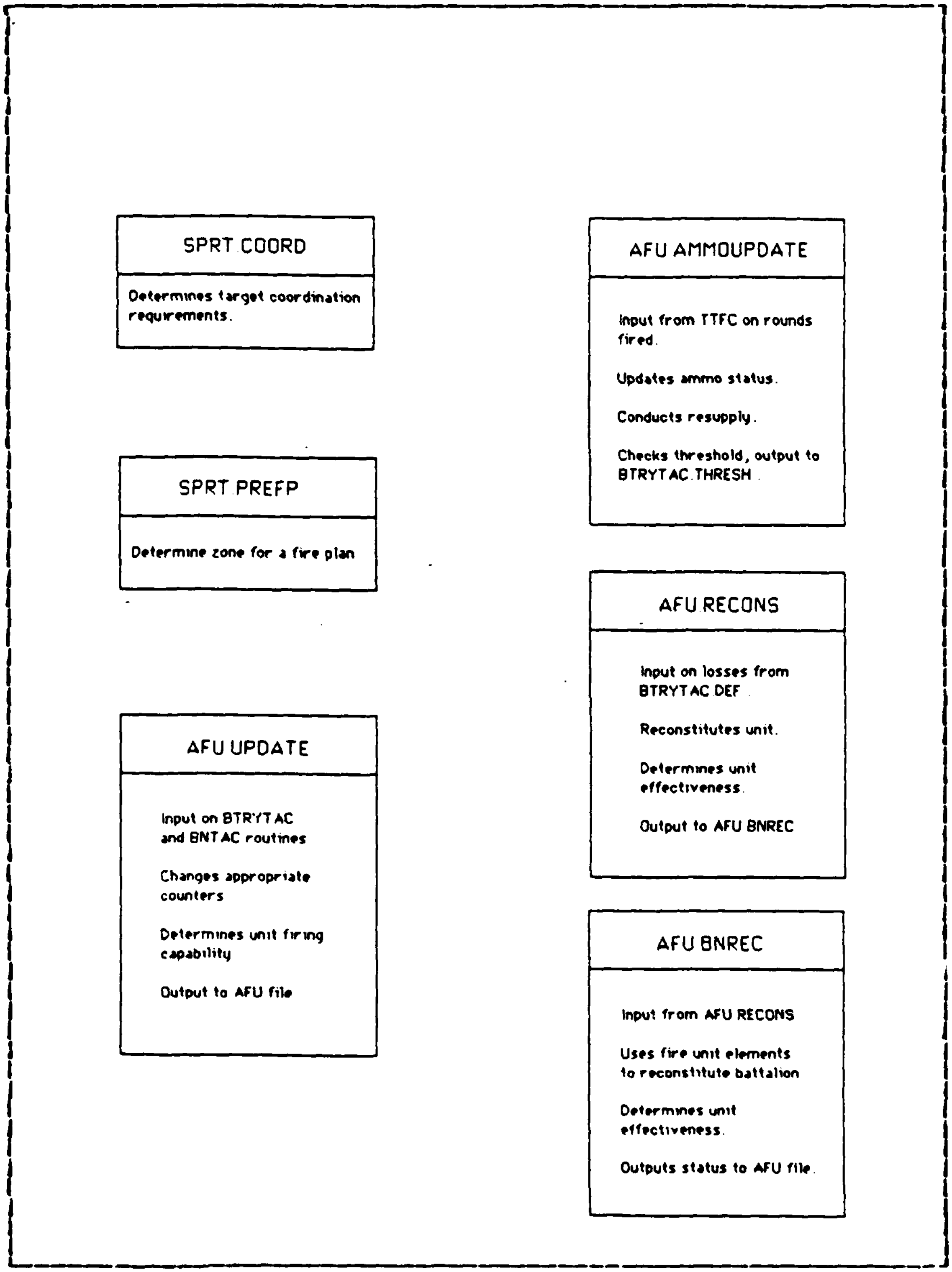


Figure 7.1 Internal Database Routines Logic

UNIT	UNITNO	ARCS	FWD NODES	REAR NODES	ZONE #	FSCOORD#
BDE						
En 1						
CO A						
CO B						
CO C						
EN 2						

NOTE: This table represents the sectors as shown:

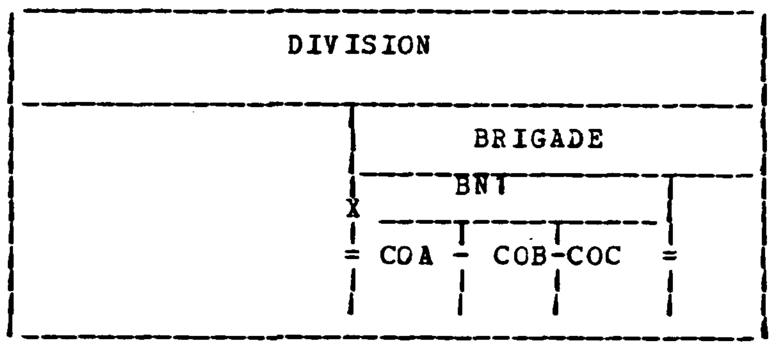


Figure 7.2 SPRT Geometric Zones

4. <u>Internal Accesses</u>

The SPRT submodule is accessed primarily by the Tactical and Technical Fire Control submodule to determine if there is a requirement for fire support coordination. When the ATI generates intelligence based on a target buildup, it accesses the SPRT to determine the appropriate fire support coordinator and forwards the information to that agency. The SPRT is accessed by the NNFP as the first step of schedule preparation to determine the proper zones of responsibility. These sectors are then sent to the ATI and used there as a parameter for the development of the target list (see Table 12).

TABLE 12

SPRT VARIABLE EXCHANGE

Routine	Call By	Call to	Argument
SPRT.COORD	ATI.MFR.TGT		TGTMSNNO. .LOC .CTL
	TTFC.FIRE MISSION		TGTMSNNO. .LOC .FSCOORD
		FO.COORD	TGTMSNNO. .LOC
		FSO.INTEL	TGTMSNNO.
SPRT.PREFP	FSO.INTEL		UNITNO.___ NNFP.n .TYPE .CAT .CTL
		ATI.PREFP	ATI.ZOR. .1 .2 PREFP. .TP .AGE

5. Routines

Routine SPRT.COORD determines whether a fire mission requires coordination and the appropriate fire support agency with which to coordinate. The routine receives a target location and FSCOORD indicator from Routine TTFC.MFR.TGT and determines the unit zone in which the target lies. For the zone, the routine then determines the FSCOORD, compares this with the target FSCOORD and, if they are the same, outputs a mission coordination flag to Routine TTFC.FIREMISSION. If the FSCOORD's are different, the target data is output to Routine FO.COORD for the appropriate forward observer.

Routine SPRT.PREFP determines the geometric zones to be used by the ATI during its search for targets for inclusion in a fire plan. The routine receives a unit designation from Routine FSO.INTEL and, for the unit, determines the corresponding geometric zone and the zone of its higher headquarters. These zones are then output to Routine SPRT.PREFP.

C. ARTILLERY FIRE UNIT SUBMODULE

1. General

The Artillery Fire Unit (AFU) maintains the status and capabilities of all fire units and the battalion FDC to include the current tactical status, equipment status and ammunition status. Additionally, it is used to maintain status flags for a variety of areas.

The AFU is primarily a matrix operation with counters but does contain logic used by the submodule to determine if any thresholds have been exceeded. The organization of the matrix is shown at Figure 7.3 .

2. Database

The database for the AFU is established by inputting the capabilities of the equipment associated with the battalion. The ammunition supply rate (ASR/CSR) is also input as well as the resupply parameter (see Table 25).

3. User Input

The user must input the information for each type equipment represented in the model which is available to the battalion and values for tactical thresholds maintained by the AFU. A list of this equipment and the data requirements are shown in Table 26 .

EQUIP/PERS	HOWITZERS A1 A2 A3 A4	FDC 1	HOWITZERS A5 A6 A7 A8	FDC 2	BTRY TOTAL
HOWITZER PRIME MOVER FDC TACFIRE RT 524 MINMAN MINMANOH	THIS SECTION CONTAINS FLAGS TO INDICATE THE STATUS OF MAJOR EQUIPMENT AND PERSONNEL TYPES.THE LEVEL REPRESENTED IN THE TABLE SHOULD CORRESPOND TO THE LEVEL OF RESOLUTION IN THE MODEL				

AMMUNITION	HOWITZERS A1 A2 A3 A4	HOWITZERS A5 A6 A7 A8	BTRY
HE HC WP ILLUM DPICM RAP RAAM CLGP	THIS SECTION MAINTAINS A COUNT, BY VEHICLE, OF THE AMMUNITION ON HAND		

THRESHOLDS	1st PLT	2nd PLT	THRESHOLD
# VOLLEYS OUT OF RG % ATTRIT TIME IN PSN	THIS SECTION CONTAINS A LIST OF THRESHOLDS FOR MOVEMENT WHICH ARE PERIODICALLY UPDATED		

DATA	
PSN TIME OCCUPIED RDS SINCE RESUP TIME SINCE RESUPPLY IAS PSNALT1 PSNALT2 13B POOL 13E POOL FU.nARCS PSNRDS NUMPSN PSNTIME	THIS SECTION CONTAINS DATA AND COUNTERS ON ATTRIBUTES OF THE UNIT WHICH ARE EXPLAINED IN APPENDIX B

STATUS	
IPRF NOCONFLICT FLTFIRE	THIS SECTION CONTAINS FLAGS TO INDICATE THE CURRENT STATUS OF THE UNIT. THE FLAGS ARE EXPLAINED IN APPENDIX B

Figure 7.3 Battery APU Matrix

4. Internal Input and Accesses

The AFU submodule is accessed by nearly every submodule in the field artillery model. Input comes from the Battery Fire submodule at the end of every mission. This report lists the type and amount of ammunition expended and the number of volleys fired. The battery provides logistic updates whenever equipment status changes which is then reflected in the matrix. The AFU also receives messages when a unit's tactical situation changes such as, in position ready to fire, march ordered, and in conflict.

The AFU provides output data to the appropriate submodule whenever a threshhold is exceeded. Movement thresholds are reported to the battery tactics submodule, ASR violations and ammunition shortages are reported to the LOGISTICS Module.

Queries of the AFU database are made by the TTFC during the preparation of every fire order and by the battery firing submodule prior to firing (see Table 13).

5. Routines

Routine AFU.AMMOUPDATE updates the ammunition status after firing or battle damage, and conducts internal resupply. The routine receives the number of rounds fired, by howitzer, from Routine BTRY.SHOOT. It then subtracts the rounds from the appropriate equipment, updates firing counters, insures that the unit is not exceeding its sustained rate of fire and determines whether the unit is exceeding its controlled supply rate (CSR). If the CSR is being violated, the data is output to the Logistics module. While decrementing ammunition counters, the routine determines whether the unit ammunition configuration is below the established thresholds and, if so, passes control to Subroutine AFU.AMMOUPDATE.RES which conducts internal resupply. For ammunition vehicles which are emptied during the resupply, control is passed to the Movement module.

TABLE 13

AFU VARIABLE EXCHANGE

Routine	Call By	Call to	Variable
AFU.AMMO UPDATE	BTRY.SHOOT		For how 1-n .AMMO.N .NUMRDS
		BTRY.TAC.DEC	PLT.NSTATUS =.THRESHOLD .N
		LCG MODULE	
		MOVE MODULE	
AFU.UPDATE	BTRY.TAC.DEC		IPRF = MOVE
	BTRY.TAC.DEF		NOCONFLICT= NO
	BTRY.TAC.OCC		IPRF = YES
AFU.RECONST	BDA MODULE		loss data
		AFU.BNRECONS	PLT.NSTATUS =
AFU.BN RECONST	AFU.RECONST		PLT.NSTATUS
		BNTAC.THRESH	PLT.NSTATUS
		AFU.RECONST	element counters

Routine AFU.UPDATE updates the counters in the AFU file as required and, as such, receives input from a variety of sources. Routine BTRYTAC.DEC changes the flag indicating the unit is moving, Routine BTRYTAC.DEF changes the

NOCONFLICT flag when a fire unit is engaged and Routine BTRYTAC.OCCUPY resets all position counters after the unit occupies a new position. The routine checks all thresholds after every change and, if one is exceeded, outputs the data to Routine BTRYTAC.DEC. If no threshold is exceeded, the routine terminates.

Routine AFU.RECONSTITUTE accounts for battle losses and reconstitutes the unit into a viable force, if possible. The routine receives loss data from the Battle Damage Assesment module, decrements all appropriate counters, determines the equipment status and cross-levels howitzer personnel to obtain the maximum operational howitzers possible. Based on the number of operational howitzers, the routine determines whether the unit is effective and passes control to Subroutine AFU.RECONSTITUTE.FDC which performs similar actions for the FDC's. Control is then passed to Subroutine AFU.RECONSTITUTE.RPT which models the time required to reconstitute, resets the firing status counters and determines the unit firing capability. The unit status is then output to Routine AFU.BNRECONST.

Routine AFU.BNRECONST receives input on a unit that has received casualties from Routine AFU.RECONSTITUTE. If the unit is still effective, the data is output to Routine BNTAC.THRESH. For ineffective units, the assets remaining are redistributed to other battalion units, and are then output on the Movement Module. The routine then recomputes the battalion attrition level, determines whether the value exceeds the user input value for increasing the importance of preserving the artillery, and outputs this data to Routine BNTAC.THRESH.

D. FUNCTIONAL DATA REPRESENTATION

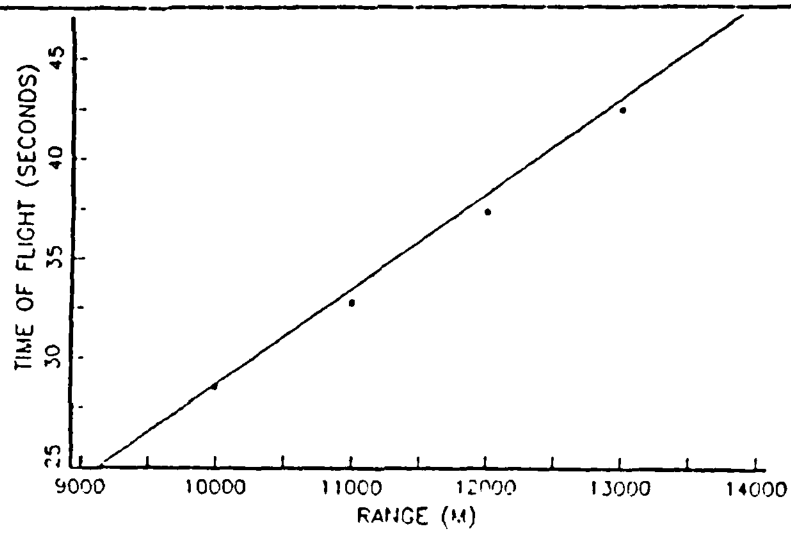
1. General

The field artillery module is one small, albeit significant, portion of a Corps-level model. As such, it is imperative that the execution time of the FA module does not become prohibitive at the highest level of resolution simulated. Current models use a significant number of look up tables to portray the data necessary to simulate field artillery actions. For example, firing data is dependent on the range from the gun to the target. This range dictates several propelling charges which can achieve the given range. The charge selection, together with the range, determines the elevation which, in turn, determines the trajectory and time of flight of the projectile and the range and deflection probable errors of the impact. Representation of this data with any reasonable degree of accuracy requires matrices, by charge, in 100 meter range increments for each data element listed above. For a M109 series howitzer, this would consist of 10 charge matrices with approximately 40 range entries for each of the five elements above (10x40x5 matrix) which must be accessed for <u>every round fired</u>. This approach significantly increases the execution time of the artillery portion of the model and is clearly unacceptable. Additionally, impact location error modelling has been done by sampling from a bivariate normal distribution which, in an expected value model, would result in no firing error.

In an effort to alleviate these shortcomings, all data for the field artillery module has been analyzed and, where feasible, functional forms have been developed to approximate the data. The initial analysis revealed that only the firing data was readily amenable to functional representation. Because firing data is howitzer dependent, the functional forms for all howitzer combinations are not included in this thesis. The methodology used to create the functicnal representation is explained below using data for the M109A2 self propelled howitzer as an example.

2. Methodology

The entry argument for all firing data is the gun to target range. Table xvii of the Tabular Firing Table gives the preferred charge(s) for a given range based on the probable firing errors associated with the charge(s). In instances where two charges are prescribed, current artillery doctrine is to select the lower charge to increase tube life. Using this criteria, the charges for the M109A2 can be specified as a function of range. The data for time of flight, range probable error and deflection probable error for the appropriate charge were then plotted as a function of range. Curves were developed for the data for each element and equations developed to approximate the curves (see Fig 7.4 through Fig 7.6) using least square approximation techniques.



$$Y = -19.497 + 0.0048171 \times X$$

Figure 7.4 Time of Flight vs Range

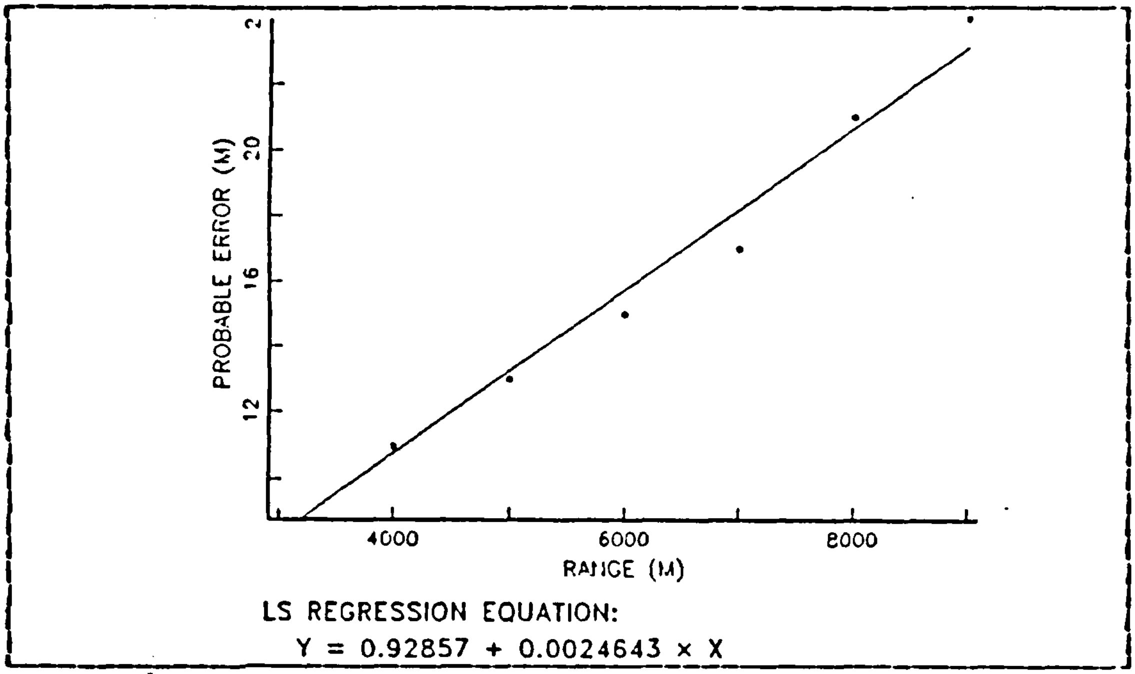


Figure 7.5   Range Probable Error vs Range

In some instances, discontinuities in the data required that several equations be developed to accurately represent the data for some elements. The functional forms and results of the tests are shown in Table 14 .

The analysis of trajectory curves required a similar but more detailed approach. Since the trajectory for a charge varies with the range (due to the muzzle velocity and elevation), a family of curves had to be developed to represent the various charges (see Figure 7.7). This repesention results in an error of less than 40 meters in the trajectory which is considered an acceptable tradeoff for the significant increase in computational speed.

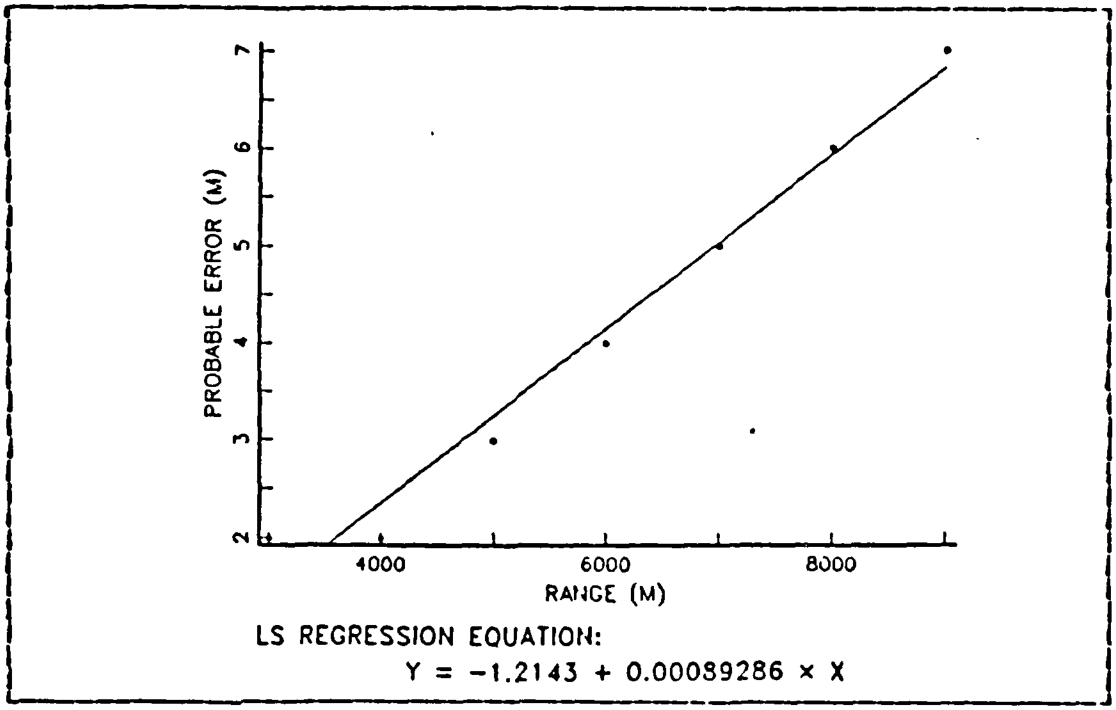


Figure 7.6 Deflection Probable Error vs Range

3. Future Analysis Required

The selection of ammunition type and quantity to fire on a given target appears to be amenable to representation in functional form. While our initial efforts failed to yield a satisfactory solution, the ammunition selection process should be reevaluated after the development of a generalized target value system. Correlation of target value to ammunition type or quantity would further reduce the tabular database and result in another significant decrease in the module execution time.

TABLE 14

FUNCTIONAL EQUATIONS TO REPRESENT FIRING DATA

FOR RANGE	CHG	TRAJ EQN
RG<2400	5GB	Y=0.19286RG-0.00010179RG**2 +8.2986E-9RG**3
2400<RG<6000	5GB	Y=1.7857+0.29454RG-0.000040774RG**2 -1.3889E-9RG**3
6000<RG<8000	5GB	Y=9.0417+0.42046RG-0.000046452RG**2 -1.5515E-9RG**3

This analysis could be continued to the system maximum range of 30000 meters

---

TOF	0<RG<9000	t=-1.109+0.0037*RG
	9000<RG<18000	t=-19.497+0.0048*RG

RANGE PE = 0.92857+0.00246*RG

DEFLECTION PE = -1.214+0.0009*RG

RG = range from the gun to the target, in meters

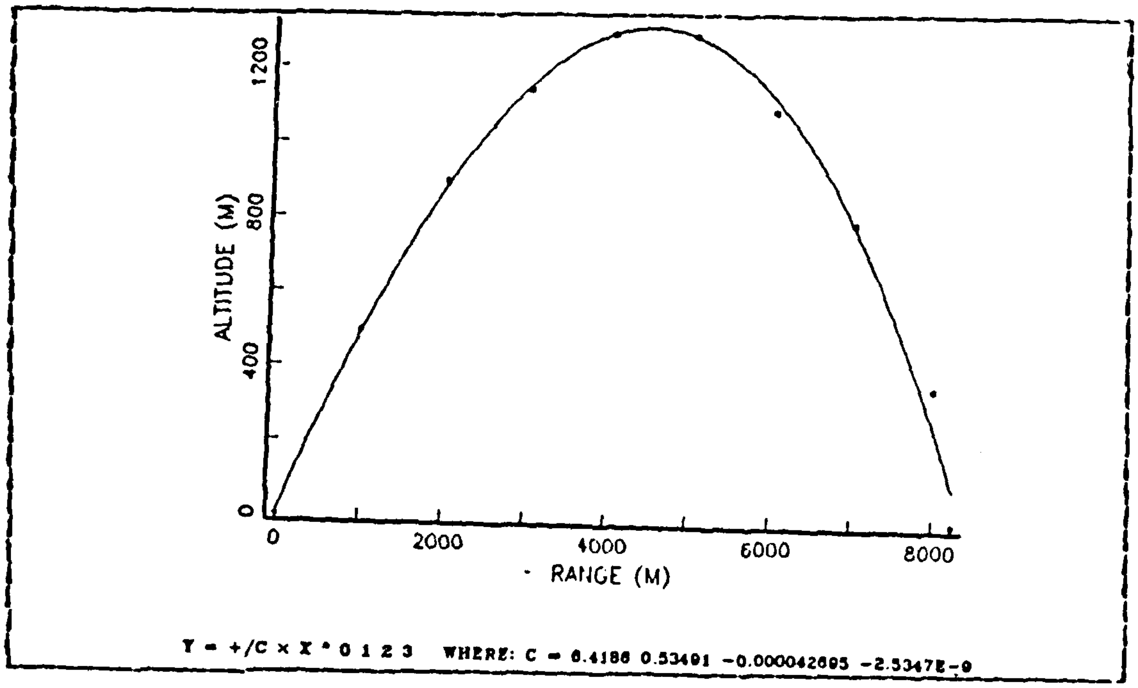


Figure 7.7 Sample Charge 5GB Trajectory

VIII. SUMMARY AND CONCLUSIONS

A. SUMMARY

1. The Field Artillery Module

This thesis presents a different methodology to model the actions of the field artillery for the Airland Research Model (ALRM). When combined with the thesis of Cpt. Robin Lindstrom, the thesis provides a representation of all activities of a field artillery battalion except for nuclear and chemical target prosecution. While dependent on other theses to properly adapt to AIRM methodology, this thesis has been written to provide a model which requires only coding to become an operational module of the ALRM. Subsequent development of a Corps/Division command and control module, and a Corps nuclear and chemical target module would provide complete representation of all field artillery entities which can be assigned to a theatre of operations.

2. Improvements to the Module

The field artillery module has been designed in extremely modular form to facilitate improvements, with each submodule performing a single task. Improvement to, or change of the existing logic requires change only to the subroutine that contains that logic, given continuity with the established variable exchanges listed for the routine. While much of the logic may be fine tuned, the following decision logic requires changes based on theses which have not been published.

a. Application of Risk to FSO Asset Selection

The FSO asset selection outlined in Routine FSO.ALLCCATE is designed to select assets based solely on a quantitative analysis of their utility. A submodule which accounts for the risk status of the unit should be developed and incorporated to the logic.

b. Functional Representation of Ammunition Selection

Firing data has been reduced from tabular form to functional form which should greatly reduce both the database requirement and the computational time for firing actions. Upon the completion of the generalized value system, ammunition selection criteria should be evaluated to determine whether they are amenable to functional representation.

3. <u>Extensions of the Module</u>

. In addition to incorporation to the Airland Research Model, this thesis has other potential uses.

a. Use in the FAST Model

The United States Field Artillery School (USAFAS) has expressed an interest in using the decision logic methodology in their analytical model, FAST. Use of this logic should significantly improve the credibility of its results while retaining the model's simplicity and speed of execution.

b. Interactive Field Artillery Trainer for FSO's and FDO's

In my experience, the two least trained officers in an artillery battalion are the FDO and the FSO. This is due to the requirement to establish a relatively complex command post exercise to properly train these officers. This thesis has the potential to be adapted to provide this training on a microcomputer. Using databases from existing CPX's, varied scenarios could be provided. The officers could react to situatuions as they occur and compare their input to the program generated solution. This would provide an accessible and timely training tool for artillery battalions.

B. CONCLUSIONS

This thesis provides the Airland Research Model with the ability to simulate all types of field artillery and should be incorporated into the model. When appropriate, those areas outlined in paragraph A2 above should be investigated for possible improvement to the methodology. Additionally, the thesis will be forwarded to the Field Artillery School for use in their model, and for its possible adaptation as an interactive field artillery trainer.

APPENDIX A

LIST OF ABBREVIATIONS AND TERMS

AFU	Artillery Fire Unit module of TACFIRE
ASR	Available supply rate
ATI	Artillery Target Intelligence module of TACFIRE
ATI:MFR	Artillery Target Intelligence mission fired report
BCS	Battery Computer System
CA	Counteracquisition category of targets
CASTFOREM	The brigade level simulation under development by TRASANA
CENTCOM	United States Central Command
CF	Counterfire category of targets
CM	Countermaneuver category of targets
CSR	Controlled supply rate
C3	Command, control and communications category of targets
DS	Direct support mission
FISSTAC	The simulation of the TACFIRE software used by the Field Artillery Center
FDC	Fire Direction Center
FIST	Fire Support Team
FLOT	Forward line of troops
FO	Forward observer
FSE	Fire Support Element
FSO	Fire Support Officer
FY	Fiscal year
GS	General support mission

IPRF	In position, ready to fire
MTBF	Mean time between failures
MTTR	Mean time to repair
M102	The 105mm towed howitzer
M109A2	The 155mm self-propelled howitzer
M110A1	The 8 inch self-propelled howitzer
M198	The 155mm towed howitzer
NATO	North Atlantic Treaty Organization
NNFP	Nonnuclear Fire Plan module of TACFIRE
RAM	Reliability and maintainability factors
SEAD	Suppression of enemy air defense category of targets
SPRT	Support module of TACFIRE
STAR	Simulation of Tactical Alternative Responses model
TAB	The target acquisition battery
TTFC	Tactical and Technical Fire Control module of TACFIRE

APPENDIX B

VARIABLE LIST AND EXPLANATION

%CTL -the percent of fire units that a battalion TOC can control from its current location

AAn -the fastest avenue of approach into defensive sector n

AC/PMBL -the ammunition basic load for an ammuniton carrier or howitzer prime mover

ADAPK(I,N) -the probability that asset I will be killed by target defense N

ADJVAL -the computed adjustment (based on a normal distribution) to be applied to the target value by the FDC to determine the target's priority of engagement

ADJBNMSNTIME -the average battalion mission processing time after subtracting the time wasted processing missions by fire units that cannot fire (minutes)

AMCTIME -the designated time for a mission which is controlled as an "at my command"mission to be fired (clock time)

AMMOn -the ammunition to be fired in a mission with selection priority n

AMMOn.AC -the number of rounds of type n on a particular ammunition carrier

AMMOn.BL -the basic load of ammunition type n for an ammuniton section vehicle

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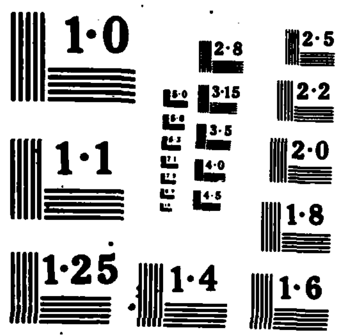

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AMMOn.EXP -the number of rounds of type n expended during a fire mission by a particular howitzer section

AMMOn.HOW -the number of rounds of type n on a particular howitzer

AMMOn.VOLLEYS -the number of volleys of ammunition type n to fire on a given target

ANG -the computed angle from the gun-target line and due north based on the impact of the rounds (mils)

ANGLE -the angle between the gun-target line and due north (mils)

ANGLEERROR -the angle between the gun-target line and the gun-impact line (mils)

EP.n -the engagement point in defensive sector n of a fire unit. This becomes a howitzer supplementary position if the fire unit is in danger from a ground threat

ASR -a flag for each type ammunition that indicates whether a fire unit is exceeding the resupply rate

ASSET.nAVAIL -a counter to indicate whether the response time of an asset is rapid enough for it to be considered in the attack of a given target

ATI.ZCR1 -the zone of the unit that requests the artillery to prepare a fire plan

ATI.ZOR2 -the zone of the higher headquarters of the unit that requests the artillery to prepare a fire plan

ATT -the current percent of attriton of the battalion's howitzers

ATTKCOUNT -the number of hostile actions against a battalion's assets during an interval of the battle

ATTKTIME -the computed time between a fire unit's request to move due to an anticipated threat and the realization of that threat. This is a measure of the battalion's responsiveness in issuing orders (minutes)

AVAILFU -the number of fire units that are capable of firing (PLTFIRE=YES) at a given instant of the battle

AVEATTKTIME -the average time between a fire unit's request to move due to a threat and the realization of that threat (minutes)

AVEBNMSNTIME -the average time the battalion spends processing a fire mission from request for fire until end of mission during an interval of the battle (minutes)

AVEDT -the average response time for an asset that must be diverted (minutes)

AVEMSNTIME -the average time for the battalion to fire a mission (minutes)

AVEORDERTIME -the average time required for the battalion to reach a decision and disseminate a movement order (minutes)

AVETOS -the average response time for an air asset that was "on station" when requested (minutes)

BLOCKNO -the fire plan category of the target. This factor determines the relative location of a target in the fire plan sequence

BNMSNTIME -the total time spent by the battalion's assets processing an individual fire mission (minutes)

BNNUMVOL -the cumulative number of volleys fired by the battalion since the beginning of the current operation

BNTIP -the cumlative time that battalion elements have been in position (minutes)

BTRY.AMMOn -the number of rounds of type n on hand in a given fire unit

BTRYBLn -the fire unit basic load of ammunition type n

BTRYMINn -the level of ammuniton n within a given fire unit that triggers a request for external resupply

BTRYTIME -the maximum time that an individual fire mission can be active without being fired or revalidated (minutes)

CHG -the propelling charge selected based on the gun-target range. This factor determines the equatins to be used in computing firing data

CSR -the number of rounds per tube per day that are available for firing

DETRATE -the rate of detection (in detections/round) for fire units

DIRFIRERG -user input distance at which targets are considered to be engageable by direct fire (meters)

DIVTIME -the cumulative time required for assets to respond which must be diverted (minutes)

Dn -the distance from a fire unit to a potential ground threat (meters)

DPn -the maximum distance in defensive sector n from which a fire unit can be engaged by direct fire (meters)

EGAIN -the expected gain from employing a specific asset against a given target

ENDDIST -the expected distance from the current position to the endpoint (meters)

ENDTIME -the next time that all fire units will be available to fire during the fire planning sequence (minutes)

E(RESPONSE) -the computed expected time until a particular asset can engage a given target (minutes)

ENGRG -the expected range of engagement if a particular asset is employed against a given target. This is a function of the target location and speed and the response time of the asset (meters)

ENGSTATUS -a flag indicating whether a maneuver unit is expected to engage a target. This factor is used by the FO to discount a target's value to the FA

ENGTVALEFT -the quantity of enemy value which a maneuver unit can engage, given its current status and position strength

ERRDF -the deflection error in firing based on the range and charge (meters)

ERRRG -the error in range from firing based on the range to the target and the charge selected (meters)

ETR.N -the expected response time of asset n given the current status of the asset (minutes)

EXCESS -the number of personnel by MOS in a particular fire unit that exceeds the unit's minimum manning requirement

FDTIME -the computed time required to process a fire mission at the battalion FDC (minutes)

FDTIME.MEAN -the mean time used to compute FDTIME (minutes)

FDTIME.SD -the standard deviation used to compute FDTIME (minutes)

FIRETIME -establishes the time line required during a schedule for the engagement of an individual target (clock time)

FIREUNITn.PRI -the priority used to rank fire units for selection to prosecute a missicn

FMMOD.CW -combining weight parameter that must be met before the ATI will generate a fire mission from intelligence data

FMMOD.DOP -degree of protection parameter that must be met before the ATI will generate a fire mission from intelligence data

FMMOD.RV -report value parameter that must be met before the ATI will generate a fire mission from intelligence data

FSCOORD -the agency responsible for coordinating all fire support into a given zone

FO.NSTATUS -a counter indicating whether the FO can process fire missions

FOMAX -user input maximum number of missions which the FO can process simultaneously

FOMSN -a counter of the number of missions currently active with a given FO

FU.NARC -user assigned arcs on the network which are the primary area of operation for fire unit n

FU.NOPEN -a flag used by the NNFP to indicate that fire unit n is available to schedule firing for a specific period during the fire plan

FU.NRG -the gun-target range for fire unit n to a given target (meters)

FUMOVE -the number of fire units that have moved to positions outside a TOC's span of control since the TOC's occupied its current position

HHR -the designated time to begin an operation. This time is used in scheduling nonuclear fire plans (clock time)

HOWBLn -the howitzer basic load of ammunition type n

HRT -the computed time for a howitzer section to process a fire mission (minutes)

HRT.MEAN -the mean time used to comput HRT (minutes)

HRT.SD -the standard deviation used to compute HRT (minutes)

HRTMAX -the largest (slowest) HRT in a fire unit. When the method of control is "at my command" or "TOT", it determines the time the unit is ready to fire (minutes)

HQZOR.SECTOR -the designated sector of the headquarters of a fire unit that has requested preparation of a fire plan

HYTIME -the computed time required for a fire unit to conduct an emergency (hasty) displacement (minutes)

HYTIME.MEAN -the mean time used to compute HYTIME (minutes)

HYTIME.SD -the standard deviation used to compute HYTIME (minutes)

IMPACTTIME -the computed time that fired rounds will land in the target area (clock time)

IMPACTLOCx -the computed easting location of the impact of a round or volley fired

IMPACTLOCy -the computed northing location of the impact of a round or volley fired

IPRF -a counter that indicates that a fire unit is in positon and is ready to fire

LOS -counter indicating whether the FO has line of sight with the target being engaged

LOSS.N -the expected loss, given that asset n is employed against the target

MAXADA -a flag indicating the most effective air defense system capable of defemding a given target

MAX.TFNSIZE -the maximum size ground threat that a fire unit will voluntarily fight in a direct fire battle. A 0 will cause movement whenever threatened

MAXATT -the attrition point, in percent, at which the survivability of the artillery force takes increased value with respect to mission accomplishment and lower probabilities of detection become acceptable (PROBMIN2, PROBMAX2)

MAXBNMSNTIME -the maximum acceptable average time for the battalion to prosecute targets. It is used as an indicator of mission accomplishment and, when not met, becomes restrictive to movement (minutes)

MAXFPTGT -user input maximum number of targets to be included in a fire plan

MAXRG -the maximum range of a given type howitzer system (meters)

MAXTGTDIST -the width of the battery sheaf. This factor is used by the FO to determine target location and the effects of firing on a target (meters)

MAXVOL -the maximum number of volleys to be fired at any target during a single fire mission

MIN%CTL -the minimum percent of firing units that the TOC must be able to control from its current position. When the actual is less than this value, the TOC displaces

MINMAN -the minimum manning level for an entity to be effective (.FDC,.HOW,.AC). When below this level, the section becomes NOTOP.MAN

MINTP -the minimum target permanence value that will be maitained as intelligence

MOTIME -the computed time required for a fire unit to prepare for movement (minutes)

MOTIME.MEAN -the mean time used to compute MOTIME (minutes)

MOTIME.SD -the standard deviation used to compute MOTIME (minutes)

MOVE -computation for various assets as to whether a given target is classified as stationary or moving based on target speed and the anticipated reaction time of the asset

MSNCTR -the number of fire missions being processed by the battalion FDC at any given instant

MSNMAX -the maximum number of fire missions that a battalion FDC can process simultaneously

MSNTIME -the time spent processing a fire mission that cannot be fired (minutes)

MU -user input mean of a normal distribution which is used to determine ADJVAL to be applied to target value in computing a target's priority of engagement

MVRRATE -the expected rate and direction of movement of the supported manuever element for the next phase of the operation. This value is used by the FA to determine the sequence of positions to occupy during that phase (meters per hour)

NEWTIME -the clock time that a fire unit which has exceeded its sustained rate of fire can resume firing

NNFPn -non-nuclear fire plan number n

NNFPn.CAT -the major category of targets to be included in fire plan n. A category of all will include all targets in the supported unit's area (up to the specified maximum)

NNFPn.CTL -the method of control of the firing of fire plan n (timed-HHR, on call-OC)

NNFPn.TYPE -flag indicating the type of fire plan to prepare (group of targets or schedule)

NOATTK -the number of times that battalion assets have received hostile activity

NOCONFLICT -a counter that indicates whether a fire unit is being engaged by hostile elements

NOTOP.BDA -a counter to indicate that a particular piece of equipment is not operational due to battle damage

NOTOP.MAN -a counter to indicate that a particular piece of equipment is not operational due to a lack of personnel

NOTOP.OR -a counter to indicate that a particular piece of equipment is not operational due to mechanical failure

NOUSE -the cumulative number of times that an air asset which must be scrambled has been employed

NOVOLn -the number of volleys fired by fire unit n during a fire mission

NOVOLFU.n -the number of volley prescribed for fire unit n to fire during a missicn

NSTAY -the minimum number of fire units that must have an immediate action status of STAY

NUMDET -the cumulative number of times that a battalion's asset have been detected by the enemy as evidenced by adverse action occurring to the units

NUMFAIL -the cumulative number of times since the start of the cperation that the battalion's units have received adverse actions

NUMFU -the number of fire units required to prosecute a fire mission

NUMHOW -the number of operational howitzers in a given fire unit

NUMMAN.XXXn -the number of personnel required for a piece of equipment (XXX=.FDC,.HOW,.AC) which is NOTOP.MAN to become operational

NUMMANOH -the number of personnel in a fire unit of a particular MOS. This is used to cross-level personnel between units

NUMRAY -the number of counterfire rays that intersect at a given point

NUMSIG -user input number of standard deviations to be applied to a specified normal distribution to compute ADJVAL

NUMSYS -the number of a given type system in a maneuver unit that are currently capable of engaging a given target

NUMTGTS -the number of targets that are included in a e fire plan

NUMTGTx -the number of targets in the radius x

NUMUSE -the cumulative number of times that an air asset has been diverted to engage targets

NUMVOL.FUn -the designated number of volleys to be fired by unit n on the current target

NUMVOL -the number of volleys that a fire unit has shot from its current postion

NUMVOLn -the number of volleys of ammunition type n to be fired at a given target

OCCTIME -the computed time for the TOC to become operational after its arrival in a position (minutes)

OCCTIME.MEAN -the mean time used to compute OCCTIME (minutes)

OCCTIME.SD -the standard deviation used to compute OCCTIME (minutes)

OPLOC.n -the location of the observation post in the fire unit defensive sector n

OPSEC.n -the primary sector of observation for OPLOC.n

ORDERCOUNT -the number of movement decisions processed by the battalion during an interval of the battle

ORDERTIME -the computed time it takes the battalion TOC to make and disseminate a movement decision (minutes)

ORDERTIME.MEAN -the mean time used to compute ORDERTIME (minutes)

ORDERTIME.SD -the standard deviation used to compute ORDERTIME (minutes)

PEREFF -the percent of effects on the current target from firing

PK -the probability that a certain asset can successfully engage a given target

PLANTGTDIST -the distance between the current target and a planned target. This distance is used in determining whether to use the planned or actual target location

PLOSS.n -the probability of losing asset n if employed against the current target which has given defenses

PLTn.STATUS -a fire unit counter that portrays the current activity of the unit

PLTFIRE -a counter that indicates whether a fire unit meets the criteria required to conduct fire missions

POTENDPTk -a node identified as a possible end point (goal) for use in the determination of the optimal sequence of positions for a fire unit

PRAVAIL -the perceived probability that an asset will be available to engage a target based on its battle performance to date

PRIASSET -a matrix of target types and maneuver assets which establishes, for each type target, the priority with which to consider assets for direct fire engagement

PRICAT -the current category of target designated as the priority for FA engagement

PROBCAS -the probability of detection of a friendly unit that is overflown by a hostile aircraft

PREFP.AGE -the maximum age of intelligence data to be used in preparing a target list for a fire plan

PREFP.TP -the permanence level which a target must exceed foe inclusion in a target list for a fire plan

PROBDET -the perceived probability of detection for a fire unit or the TOC based on its time in position and the number of rounds fired from the position

PROBMAX -the maximum acceptable PROBDET for a unit. When this value is exceeded, the element moves without regard for the mission

PROBMAX2 -the revised (lower) PROBMAX that corresponds to the requirement to preserve the artillery at MAXATT

PROBMIN -the minimum acceptable PROBDET. When the value exceeds this, mission accomplishment and survivability are weighed prior to any movement

PROBMIN2 -the revised (lower) PROBMIN that corresponds to the requirement to preserve the artillery at MAXATT

PSNEND -the final postion (goal) which is selected from all POTENDPTk's and is used to determine the optimum sequence of positions for a fire unit

PSNONE.n -nodes 1-n considered as potential first positions for fire unit occupation

PSNTWO.m -nodes 1-m considered as potential second positions for fire unit occupation

PSNVAL.x -the computed value of the filed artillery relevant attributes of position x

Pn -polynomial approximations computed in determining ADJVAL

Q -the computed target combination factor

QMOD -user input value which must be exceeded before targets can be combined

Rs -the similarity between two targets being considered for combination

RATE -the sustained rate of fire that a particular fire unit has achieved from its current position (rounds per minute)

RDSEXP -the number of rounds that a particular fire unit has expended from its current position

RECONSTTIME -the computed time required for a fire unit to reconstitute after an attack (minutes)

RECONSTTIME.MEAN -the mean time used to compute RECONST TIME (minutes)

RECONSTTIME.SD -the standard deviation used to compute RECONSTTIME (minutes)

REQRAY -the number of counterfire rays that must intersect within a given radius to generate a confirmed counterfire target

RESPONTIME -the actual time for an asset to respond to a requirement to engage a target (minutes)

RPF -determines the maximum allowable distance between two targets for combination to occur

RQDAMMO -the quantity of ammunition required by a fire unit to process a given mission

RQSTMOVETIME -the clock time at which a fire unit asks for battalion permission to move

RSR -the number of rounds fired by a unit since resupply

Rn -a variable computed in determining ADJVAL

SIGMA -user input standard deviation of a normal distribution to be used to compute ADJVAL

SLACK -counter indicating, by fire unit, times during a fire plan that the unit is not actively engaged in firing

Sn -the perceived ground speed of a potential threat

SUSTRATE -the maximum sustained rate of fire that a unit can achieve. Firing ceases when this value is exceeded (rounds per minute)

SVMOD -the maximum age of a target that will be processed for combination

TBMODx -the number of targets found in the database that are within x km of the given point for x = .5,1.0,1.5 This is used as output for target buildup indication and is primarily for nuclear and chemical target analysis

TD.xy -the time required to move from position x to position y. This value is multiplied by PSNVAL.x to determine the relative value of the sequence of positions xand y (minutes)

TE -the amount of time in which a fire unit expects to be engaged by a ground threat based on a time-distance factor (minutes)

TFD -the computed technical fire direction time at the fire unit FDC (minutes)

TFD.MEAN -the mean time used to compute TFD (minutes)

TFD.SD -the standard deviation used to compute TFD (minutes)

TFLOT.n -the expected time until the current target reaches the FLOT (minutes)

TGTAGE -the maximum time to maintain any target as intelligence (minutes)

TGTCAT -the general category of a given target which the FSO uses to estimate the Pk of employing various assets

TGTEFF -the percentage of effects desired on a given target

TGTMSNNO -the primary identifier of the mission

TGTMSNNO.AMMO1 -the preferred ammunition type for a given mission

TGTMSNNO.AMMO2 -the second preferred ammunition type for a given mission

TGTMSNNO.AMMO1VOLLEY -the number of volley of ammunition type 1 to be fired in a given mission

TGTMSNNO.AMMO2VOLLEY -the number of volleys of ammunition type 2 required to engage a given target

TGTMSNNO.CAL -the caliber indirect fire weapon detected by the shell report

TGTMSNNO.CAT -the mission queue category

TGTMSNNO.COORD -a flag indicating whether the mission is coordinated to fire

TGTMSNNO.CTL -the method of controlling fires by the observer

TGTMSNNO.DIR -the direction from which an incoming round was fired

TGTMSNNO.DOP -the degree of protection of personnel targets

TGTMSNNO.DTG -the date time group that the mission is originated

TGTMSNNO.EFF -the effects of fire on a target

TGTMSNNO.FIRE -the time to schedule battery firing of the mission (clock time)

TGTMSNNO.FIRESTATE -a flag indicating if the target is firing at friendly forces (meters)

TGTMSNNO.FORG -the range from the FO to the target

TGTMSNNO.FSCOORD -the designator of the fire support agency responsible for the target area

TGTMSNNO.FU -the fire unit(s) selected to engage the target

TGTMSNNO.IMPACT -the time to schedule impact of a projectile (clock time)

TGTMSNNO.LOC -the geometric location of the target

TGTMSNNO.LOCCONF -the expected error in target location (meters)

TGTMSNNO.NUMVOL1 -the number of volleys with ammunition type 1 that a given fire unit will fire during the mission

TGTMSNNO.NUMVOL2 -the number of volleys with ammunition type 2 that a given fire unit will fire during the mission

TGTMSNNO.RANK -Rank order of a target in the fire plan sequence

TGTMSNNO.RESPONSE -expected time for a direct fire target to enter direct fire range (minutes)

TGTMSNNO.RG -the range from the firing unit to the target (meters)

TGTMSNNO.RV -the TACFIRE report value of the target location based

TGTMSNNO.SIZE -the size of the array

TGTMSNNO.SPEED -the speed at which a target is moving (meters per minute)

TGTMSNNO.STATUS -flag which indicates the status of an air asset chosen to engage a target

TGTMSNNO.TOF -the time of flight of the projectile

TGTMSNNO.TOR -time the mission is received (clock time)

TGTMSNNO.TOT -the time to fire a mission designated as time on target (clock time)

TGTMSNNO.TP -the TACFIRE permanence code for the target type on the source

TGTMSNNO.TVA -the generalized value of the target

TGTMSNNO.TYPE -the target type predominant in the array

TGTMSNNO.XMIT -the time to schedul transmission of a fire mission from battalion to the appropriate batteries given the type FO (clock time)

TGTSVF -the standard volley factor to be applied to the ammunition fired on a given target

TGTTVA -the value of the current target being considered for engagement by the FO after discounting for expected maneuver unit engagement of the target

THRESHOLD.n -this is actually a PLT.NSTATUS which reflects that threshold number n has been exceeded. A list of the possible threshold entries is shown in ROUTINE ETRYTAC.DEC

TIME -the amount of time which a fire unit that has exceeded its sustained rate of fire (SUSTRATE) must stay inactive to allow the tubes to cool (minutes)

TIMEAMMO -the computed time required for internal fire unit ammunition resupply (minutes)

TIMEAMMO.MEAN -the mean time used to compute TIMEAMMO (minutes)

TIMEAMMO.SD -the standard deviation used to compute TIMEAMMO (minutes)

TIMENOW -current date time group (clock time)

TIMEOS -the cumulative response time of an asset given that the asset was on station when employed (minutes)

TIMEWASTED -the total time spent by a particular fire unit processing fire missions which the unit could not fire (minutes)

TIP -the amount of time a fire unit has been in its current position (minutes)

TOCn.STATUS -the activity indicator of TOC n

TOF -the time of flight of a projectile from the fire unit to the target which is computed parametrically based on the gun-target range and the charge selected (seconds)

TOTBNMSNFIRED -the total number of missions fired by a battalion during a given interval of the battle (minutes)

TOTBNMSNTIME -the total time spent processing missions during a given interval of the battle (minutes)

TOTTIME -the specified "time on target" (clock time)

TPn -the threshold location in unit sector n at which the unit must either displace or prepare to fight a ground threat

TPn.SIZE -the maximum size force which a fire unit will voluntarily fight in a direct fire battle.

TPAGE -the maximum time to maintain data on a target with permanence code (TPCODE) less than TPMIN (minutes)

TPMIN -the minimum target permanence level that will be maintained for any significant amount of time

TSR -the computed time since ammunition resupply for a particular fire unit (minutes)

TVAASSET.N -the value of asset n

TVACOMMIT -the available firepower of the supported maneuver which is currently committed to direct fire engagements

TVALEFT -the firepower of the supported maneuver unit which is available to engage the FO's current target

TVAMIN -the user input value which a target must exceed before a particular asset can be used to engage the target

TVATGT -the generalized value of a given target

Tn -polynomial approximation computed in determining ADJVAL

U -the computed proximity factor for two targets being considered for combination

UPDATE -the computed time to schedule the next asset update for the FSO (clock time)

U(X) -the computed utility of employing a specific asset against a given target

UNITNC -the maneuver unit assigned responsibility for a given sector of the battlefield

VAL.xy -the computed value of position y, if occupied from position x, as a part of a designated sequence of positions

Zn -probability computed by polynomial approximation of the normal distribution which is used to determine ADJVAL

ZOR.FSCOORD -the fire support coordinator for the unit zone into which a target falls

ZOR.SECTOR -the unit zone into which a target falls

APPENDIX C

EXPLANATION OF ROUTINES

ROUTINE AFU.AMMOUPDATE
updates the ammunition status after firing or battle damage and conducts internal ammunition resupply.

ROUTINE AFU.BNRECONST
allocates forces from battalion elements which have become ineffective and determines the level of attrition of the battalion's forces.

ROUTINE AFU.RECONSTITUTE
accounts for battle losses and reconstitutes the surviving forces into viable units.

ROUTINE AFU.UPDATE
updates counters in the AFU file as warranted.

ROUTINE ATI.MFR
adds target intelligence to the AFU file and determines if target aggregation is warranted. If so, the new target is checked against user input criteria to determine whether it should be output as possible target buildup data or a fire mission.

ROUTINE ATI.PREFP
determines targets that are in a given sector and meet the criteria for inclusion in a fire plan.

ROUTINE BTRY.FIRE
models the actions of the battery upon receipt of a fire mission.

ROUTINE BTRY.SHOOT
models the actions at the firing unit at the time of firing.

Routine FO.COORD
determines whether a target, which is originated by another element but falls in this FO's zone, is coordinated for firing.

Routine FO.DETECT
acquires targets and processes them to the forward observer for engagement.

Routine FO.END
ends a mission, updates the FO's counters and processes the end of mission to the artillery.

ROUTINE FO.FIREMISSION
processes fire missions from the first round fired until the mission is complete to include determining subsequent corrections, changes in the mission and determining the mission effects.

Routine FO.GENERATE
receives targets, determines their priority of engagement and, in priority, determines the method of engagement.

Routine FO.STATUS
uses input from the maneuver commander to determine the current capability of the FO to acquire targets and process missions.

ROUTINE FSO.ALLOCATE
dynamically determines the optimum asset to employ against a specific target.

Routine FSO.INTEL
acts as the information conduit between the artillery and maneuver units.

Routine NNFP.PREFP
develops schedules of fire and groups of targets for engagement.

ROUTINE SPRT.COORD
determines if a mission requires coordination and the appropriate fire support agency to which intelligence data should be forwarded.

ROUTINE SPRT.PREFP
determines geometric zones to be used by the ATI in its search for targets to be included in a fire plan.

ROUTINE TTFC.FIREMISSION
processes targets in accordance with their priority to include the method of attack, units to fire and the type and quantity of ammunition for each unit. The routine also processes end of mission reports to the ATI.

APPENDIX D
TARGET TYPES AND SUBTYPES

Tables 15 and 16 list the targets available for use in the field artillery module. The observer will classify a target as one of the listed types and subtypes based on the predominant item(s) in the target array. Fire direction logic is capable of determining the method of engagement of these type targets only. Additional target types which are desired must be input along with the fire direction selection logic to engage those target types.

TABLE 15
TARGET TYPES, SUBTYPES AND CATEGORY

TARGET TYPE	VALID TARGET SUBTYPES				
	UNKNOWN	LIGHT	MEDIUM	HEAVY	MISSILE
CENTER (C3)	X	SMALL	BN & UP		
PERSONNEL	X	INF (CM)	OP (C3)	PTL (C3)	
SUPPLY (CM)	X	AMMO	OTHER		
TERRAIN (CM)	X	ROAD	JUNCT	HILL	OTHER

TABLE 16

TARGET TYPES, SUBTYPES AND CATEGORY (CONTINUED)

TARGET TYPE	VALID TARGET SUBTYPES						
	UNKNOWN	LIGHT	MEDIUM	HEAVY	MISSILE	APC	ANTITANK
ADA (SEAD)	X	X	X	X	X		
ARMOR (CM)	X	X	X	X		X	
ARTY (CF)	X	X	X	X	X		
MORTAR (CF)	X	X	X	X			
ROCKET/ (CF)	X	X	X	X			X
VEH (CM)	X	X	X	X			X
GUN (CF)	X	X	X	X			X
ASSY AREA (C3)	X	TRP	TRP/VEH	MECH	ARMOR		
BUILDING (C3)	X	ALL					
BRIDGE (CM)	X	FOOT	PONTOON	OTHER			

APPENDIX E
TARGET SELECTION ROUTINES

A. FORWARD OBSERVER SUBMODULE LOGIC

Routine FO.DETECT

Purpose

This routine acquires targets and processes them to the forward observer for engagement

**** This routine is not developed due to the lack of an operational model. The following applies to the input required from the routine:

1. For a final protective fire (FPF), or for munitions smoke (HC), white phosphorous (WP) and illumination (ILL), the input must come from the company command module. This reflects the normal limitations placed on a forward observer.

2. The data required from the routine are:

   TGTMSNNO.
      .FORG - the FO range to the target
      .TYPE - the target type
      .SUBTYPE - the target subtype
      .LOC - the target location
      .LOCCONF - the location confidence

.SPEED - the target speed

.FIRESTATE - whether the target is firing at the maneuver unit

.DIR - the direction of travel of the target

.DIRFIRE - whether the target is being engaged by friendly direct fire

3. The routine should output the data to Routine FO.GENERATE

Routine FO.GENERATE

Purpose

This routine receives targets, determines their priority of engagement and, in priority, determines the method of engagement.

Logic

1. If the input is not a target, go to Subroutine FO.GENERATE.START

   If FO.nSTATUS = NEXT, go to Subroutine FO. GENERATE.START

2. Determine if the target is a FPF

   If TGTMSNNO.CTL = FPF, go to Routine TTFC. FIREMISSION

3. Determine if immediate suppression is warranted

   If TGTMSNNC.FIRESTATE = YES,
   TGTMSNNO.CTL = IMMED
   Go to Routine TTFC.FIREMISSION

4. Go to Subroutine .PRIORITY

Subroutine FO.GENERATE.PRIORITY

NOTE: The user must input a table to establish the priority of engagement for each asset against all possible target categories and the total TVA that each asset can engage in a given time period. This input is shown in table 18 .

1. Determine whether the target will be in direct fire range at the expected time of engagement

   if TGTMSNNO.FORG - TGTMSNNO.SPEED / AVEBNMSNTIME
   < DIRFIRERG, go to subroutine FO.GENERATE.DFPRI

2. Discount the target value based on its distance from the FLOT

   TGTVALUE = TVA * (EXP<-disc>*TGTMSNNO.FORG)

3. File the target in the FO queue

Subroutine FO.GENERATE.DFPRI

1. Determine, for the priority assets, which are capable of engaging the target

   For PRIASSET 1-n
   ENGTVALEFT = NUMSYS * ENGAGETVA
   TVALEFT = ENGTVALEFT - TVACOMMIT

If TVALEFT < 0, ENGSTATUS = no

2. Determine the value of the target by discounting its current value by the expected engagement TVA

   For PRIASSET 1-n
   If ENGSTATUS = yes, TGTTVA = TGTTVA - TVALEFT

3. File the target in the FO queue

Subroutine FO.GENERATE.START

1. Determine if the FO has the capability to process anything

   If FO.nSTATUS = no, end

2. Determine whether the FO has the capability to process another mission

   If FOMSN > FOMAX, end
   Else pop the highest priority target

3. Determine whether the target is moving

   If TGTMSNNO.SPEED / AVEBNMSNTIME < MAXTGTDIST,
   TGTMSNNO.MOVE = STA
   Else TGTMSNNO.MOVE = MOVE, go to Subroutine FO.GENERATE.ADJ

4. Determine whether the target is accurately located and warrants fire for effect

If TGTMSNNO.LOCCONF > MAXTGTDIST,
TGTMSNNO.CTL = ADJ
Else TGTMSNNO.CTL = FFE,

5. Go to Routine FSO.ALLOCATE

Subroutine FO.GENERATE.ADJ

1. Determine, for moving targets, whether the target is moving towards a planned target

If TGTMSNNC.CAT = MOVE and
If (TGTMSNNO.DIR < MAXTGTDIST) and (PLANTGT
DIST / TGTMSNNO.SPEED < AVEBNMSNTIME)
TGTMNSNO.CTL = AMC, go to Routine FSO.ALLOCATE

2. The method of control is adjust

TGTMSNNO.CTL = ADJ

3. Go to Routine FSO.ALLOCATE

ROUTINE FO.FIREMISSION

Purpose

To process fire missions from the first round fired until the mission is complete to include determining subsequent corrections, changes in the mission and determining the mission effects

1. If the input reflects firing, go to Subroutine .EFF

If the TGTMSNNO.EFF = SHOT and TGTMSNNO.CTL = AMC, FFE or FIRE, go to subroutine .EFF ADJ, go to subroutine .ADJ

2. If the input indicates that the unit is ready to fire an at my command mission, go to Subroutine .ADJ

If TGTMSNNO.CTL = AMC and btry ready flag is set, go to Subroutine .ADJ

Subroutine FO.FIREMISSION.ADJ

1. Determine if the FO is capable of adjusting

If FO.nSTATUS = no, TGTMNSNO.CTL = EOM, TGTMSNNO.EFF = UNK, go to Routine FO.END

2. Determine if the FO has line of sight with the target

If LOS = no, TGTMNSNO.CTL = EOM, TGTMSNNO.EFF = UNK, go to Routine FO.END

3. Determine whether the location confidence of the target has improved enough to fire for effect

If |TGTMSNNO.IMPACT - TGTMSNNO.LOC| < MAXTGTDIST, TGTMSNNO. = nnnnFFE, go to Routine BTRYFIRE
Else determine the new TGTMNSNO.LOC
TGTMSNNO = nnnCORR,go to Routine BTRYFIRE

Subroutine FO.FIREMISSION.AMC

1. Determine the time that the target will be in the sheaf

   TGTDIST = PLANTGT.LOC - TGTMSNNO.LOC
   AMCTIME = TGTDIST / TGTMSNNO.SPEED
   TIMEFIRE = current DTG + AMCTIME

2. Schedule transmission of TGTMSNNO.CTL = FIRE at TIMEFIRE to Routine BTRYSHOOT

Subroutine FO.FIREMISSION.EFF

1. At 5 seconds before impact, determine if the FO is capable of observing the target effects

   If FO.nSTATUS = no or LOS = no,
   TGTMSNNO.EFF = UNKN and TGTMSNNO.CTL = EOM
   go to Routine FO.END

2. At impact time, determine the effects of the firing on the targets in the area

   PEREFF = # targets affected / # targets in the array

3. Determine the mission effects, end the mission and go to subroutine FIREMISSICN.END

For PEREFF	TGTMSNNO.EFF =
>.30	DEST
.10<x<.30	NEUT
<.10	SUPP

TGTMSNNO.CTL =EOM, go to Routine FO.END

Routine FO.END

Purpose

To end a mission, update the FO's counters and process the end of mission to the artillery

Logic

1. If the target control is end of mission, decrement the mission counter and determine the time when the FO will be able to process another target. Output through the scheduler tc ROUTINE FO.GENERATE

   FOMSN = FOMSN - 1

2. Go to ROUTINE BTRYFIRE

Routine FO.STATUS

Purpose

This routine uses input from the maneuver commander to determine the current capability of the FO to acquire targets and process missions.

****** Note: The following input is required from the maneuver commander module and is used to change the FO's status, FO.nSTATUS:

COMMANDER	FO.nSTATUS
suppressed	no
moving	move
obscured	no
all others	yes

Routine FO.COORD

Purpose

This routine determines whether a target, which is originated by another element but falls in this FO's zone, is coordinated for firing.

Logic

1. Determine whether the target has moved

   If TGTMSNNO.LOC > MAXTGTDIST,
   TGTMSNNO.COORD = no, go to Routine BTRYSHOOT

2. Determine whether the effects of firing will affect a friendly unit

   If (TGTMSNNO.LOC-maneuver location) < MAXTGTDIST,
   TGTMSNNO.COORD = no, go to Routine BTRYSHOOT

3. The target is coordinated
   TGTMSNNO.COORD = yes, go to Routine BTRYSHOOT

B. FIRE SUPPORT OFFICER SUBMODULE LOGIC

ROUTINE FSO.ALLOCATE

Purpose

To determine the optimum asset to employ against a given target

1. Determine if the data is a mission request or update

   If TGTMSNNO.EFF = UPDATE or
      If FSO.nSTATUS = UPDATE
   Go to Subroutine .UPDATE

2. Determine if the input is an update of an ongoing mission

   If TGTMSNNO.STATUS = OS/PUP, go to Subroutine .AIR

3. Determine time for target to enter direct fire range:

   TGTMSNNO.RESPONSE=.RG/.SPEED

4. For assets = AH or CAS, determine (Response time) and if > .RESPONSE, asset is considered not available:

   If E (RESPONSE) > .RESPONSE, ASSET.NAVAIL= NO

5. For assets 1-n, which are available, determine the probability of loss, PLOSS.n

   For FA,MTR: PLOSS.n = 1 - exp(-PROBDET*AVEBNMSNTIME)
   For AH,CAS: find the maximum ADA threat present,MAXADA
      For MAXADA, PLOSS.n = ADAPK(I,N)

6. Determine the expected loss for each asset

```
LOSS.n = PLOSS.n * TVAASSET.N
```

7. Determine the expected gain for each asset

```
EGAIN = PKASSET*TVATGT
```

8. Determine the probability of asset availability

```
If TGTMSNNO.SPEED = 0, PRAVAIL = 1.0
Else TFLOT.n = FO.RG/TGTMSNNO.SPEED
     PRAVAIL = TFLOT.n / ETR.n
     If PRAVAIL > 1.0, PRAVAIL = 1.0
```

9. Determine the utility of employing each asset

```
U(n) = EGAIN * PRAVAIL
```

10. Select the asset with the largest utility

11. Route the request to the appropriate routine

```
For FA, output to ROUTINE TTFC.FIREMISSIONand go
 to Subroutine .AIR
For mortar, go to mortar fire direction
For AH/CAS, go to S3 Air routine
```

```
****************************************************
NOTE: The S3 Air routine must update the FSO
  data by providing input to ROUTINE FSO.ALLOCATE
  as follows:

    TGTMSNNO.EFF = UPDATE
    For the status of the asset (OS,SCR)
     RESPONTIME
```

The S3 Air must also provide status reports for the mission to include when on station (OS) and when at the pop up point (PUP)

TGTMSNNO.STATUS = OS or PUP

****

Subroutine FSO.ALLOCATE.UPDATE

1. If TGTMSNNO.EFF = UPDATE, augment the response time data

   If asset was on station:
   TIMEOS = TIMEOS + RESPONTIME
   NOUSE = NOUSE + 1
   AVETOS = TIMEOS / NOUSE

   If asset was not on station:
   DIVTIME = DIVTIME + RESPONTIME
   NUMUSE = NUMUSE + 1
   AVEDT = DIVTIME / NUMUSE

   Output the data to the FSO Table

2. If the FSO status is update, update FA,MTR table entries to reflect the current value of:

   FA,MTR: AVEBNMSNTIME

3. Determine the next time of update and schedule

   UPDATE = current DTG + 1 hour
   At UPDATE, FSO.nSTATUS = UPDATE
   Schedule

Routine FSO.INTEL

Purpose

To act as the information conduit between the artillery and maneuver units.

Logic

1. If the input is from the artillery, determine if it is a duplicate

    If TGTMSNNO.CTL = INTEL
    If TGTMSNNO.LOC = .LOC on file, end
    Else go to The MANUEVER INTELLIGENCE ROUTINE

2. If the input is a non-nuclear fire plan, pass the information to Routine SPRT.PREFP

    Input must be:
    NNFPn.TYPE - group or schedule
    NNFPn.CAT - the major category of targets or all
    NNFPn.CTL - the method of control (HHR, on call<OC>)

    UNITNO. = FSOn
    Go to Routine SPRT.PREFP

C. NONNUCLEAR FIRE PLANNING SUBMODULE LOGIC

Routine NNFP.PREFP

Purpose

The purpose of this routine is to develop schedules of fire and groups of targets for engagement

Logic

1. Determine whether the target list is too long and, if so, delete targets based on their age

```
While NUMTGTS > MAXFPTGT, delete TGTMSNNO with
 minimum DTG
```

2. Divide the targets into blocks based on their category

If TGTMSNNO.CAT=	BLOCKNO=
FA	1
C2	2
CA,SEAD	3
CM	4

3. Rank the targets, by block, according to permanence from the largest permanence (minimum mobility) to the smallest permanence (maximum mobility)

```
For BLOCKNO = 1 TO 4
 TGTNO = TGTNUM
 For TGTMSNNO 1-n
  If TGTMSNNO.TP < TGTNO.TP
   TGTMSNNO.RANK = TGTNO
 Next TGTMSNNO
 TGTNO = TGTNO - 1
Next block
```

4. Initialize fire unit available times to H-HR

```
For FU 1-n
 FU.NOPEN = HHR
```

5. Begin scheduling targets from H-HR backwards

a. Determine the minimum available time for all involved fire units and designate as the time to fire, ENDTIME

```
For selected fire units:
 If FU.NOPEN < ENDTIME
  ENDTIME = FU.NOPEN
```

b. Determine the time to fire and schedule

```
For selected fire units:
 TGTMSNNO.TOT = ENDTIME - FIRETIME
```

c. Determine the nonfiring times for the unit

```
For selected units:
 If TGTMSNNO.TOT = FU.NOPEN, next
 Else SLACK = FU.NOPEN - TGTMSNNO.TOT
  File as nonfiring time for FU.n
```

d. Schedule 1 minute to change targets

```
For selected fire units:
 FU.NOPEN = TGTMSNNO.TOT - 1
```

e. Go to next target

6. Determine whether targets with only one fire unit designated to engage can be moved into nonfiring time

```
For TGTNO 1-n
 If NUMFU = 1
  If, for selected fire unit,
```

```
SLACK + 1 > FIRETIME
TGTMSNNO.TOT = SLACK - FIRETIME
FU.NOPEN = TGTMSNNO.TOT - 1
Next TGTNO
```

7. Go to Routine BTRYFIRE

TABLE 17

FORWARD OBSERVER USER INPUT

VARIABLE	EXPLANATION
DIRFIRERG	The maximum range of direct fire weapons
FOMAX	The maximum number of fire missions that a FO can process simultaneously
MAXTGTDIST	The width of the battery sheaf. When adjustment rounds are within this distance of the target, the method of fire is changed to fire for effect

TABLE 18

FO TARGET PRIORITY USER INPUT

TARGET TYPE	ASSET PRIORITY/ENGTVA				
	TANK	APC	TOW	M60	DRAGON
ADA					
ARMOR					
ARTY					
MORTAR					
ROCKET/					
VEH					
GUN					
ASSY AREA					
BUILDING					
BRIDGE					
CENTER					
PERSONNEL					
SUPPLY					
TERRAIN					

TABLE 19

MNFP USER INPUT

Variable	Value	Explanation
MAXFPTGT	1-n	The maximum number of targets that may be scheduled in a single fire plan

APPENDIX F
FIRING SUBMODULES

A. BATTALION TTFC SUBMODULE PROGRAM LOGIC

ROUTINE TTFC.FIREMISSION

Purpose

To process targets at the battalion fire direction center (FDC) in accordance with their computed priority to include the method of attack, units to fire and the type and quantity of ammunition for each unit. The routine also processes end of mission reports to the ATI.

Logic

1. If the target control is end of mission or no fire, go to subroutine .MFR

    If TGTMSNNO. CTL = EOM or TGTMSNNO.EFF= NOFIRE, go to subroutine .MFR

2. If the target is already being engaged, send an end of mission to the originating agency

    If TGTMSNNO. LOC is within 300 meters of any active mission, TGTMSNNO. EFF = EOM.
    Output to ROUTINE FO.END

3. Determine the target mission time, augment the battalion mission counter and file in the battalion mission file

TGTMSNNO. DTG = current time
MSNCTR = MSNCTR+1

4. If the method of control is Final Protective Fire, access the battalion file for the assigned fire unit and send the missicn to ROUTINE BTRY.FIRE for that unit

5. Output target number, lccation and source to ROUTINE SPRT.COORD to begin coordination

TGTMSNNO., .LOC, .FSCOORD

6. Go to subroutine TGTPRIORITY

<u>Subroutine</u> <u>TTFC.FIREMISSION.TGTPRIORITY</u>

1. For the current priority category and the target category, determine the value of the mean and standard deviation to be used and the number of standard deviations to be applied to the target value

For PRICAT and TGTMSNNO.CAT,
MU=, SIGMA=, NUMSIG=

2. Determine the adjusted value to be applied to the target value. This approximation is atken from ref 8

Compute the normalized z-values for a N(0,1) distribution when given non-standard normal Mu and Sig values.
Z1=((NUMSIG-MU)/SIG)/2

To compute area under the curve by polynomials

```
T1= 1/( 1+.3326 * (Z1))
R1 = ( EXP (-(Z1**2)/2))/2.5066282746
```

Compute probability approximations

```
P1= ((R1 * (.4361836 * T1 - .1201676
* T1**2+.937298*T1**3))*10000+.5)/10000
```

The probabilities are output according to the standard values input:

```
ADJVAL = |2*(P1-0.5)|
```

3. Determine the adjusted target value

```
TGTMSNNO.VALUE = TGTMSNNO.TVA * ADJVAL
```

4. Store the target data in the FDC queue

If MSNCTR > MSNMAX, END else go to subroutine .ATTACK

Subroutine TTFC.FIREMISSION.ATTACK

1. If special ammunition (HC, WP, ILL) is specified, go to subroutine .AMMO

   If TGTMSNNO.AMMO = HC,WP,ILL, go to subroutine .AMMO

2. If FASCAMx is specified as the ammunition, go to subroutine .FASCAM

   If TGTMSNNO.AMMO = FASCAMx, go to subroutine .FASCAM

3. If the mission is immediate suppression, the method of fire is a fire unit two rounds, HE. Go to subroutine .FU

   If TGTMSNNO.ACT = FIRE or .CTL = IMMED, TGTMSNNO.AMMO1 = HE, NUMVOL1=2, go to subroutine .FU

4. Access the Method of Attack Table (Table 20) with the largest TVA value in the array and determine the method of engagement

   For the TGTMSNNO.TYPE with the largest TVA, TGTMSNNO.ENG = E or V

5. Access the Fire Mission Attack Table (user input) to determine if there is any commander criteria for ammunition type. If so, set the ammunition type to the specified munition and go to subroutine .AMMO

6. Access the Ammunition Priority Table (Table 21) in sequence and determine the two preferred ammuntition types

   For TGTMSNNO.TYPE, .SUBTYPE, .ACT and .SIZE,
   .AMMO1 = and .AMMO2 =

7. Go to subroutine .AMMO

Subroutine TTFC.FIREMISSION.AMMO

1. Access the Fire Mission Attack Table (user input) with the method of engagement and determine, for the target type, whether attack criteria has been specified

   For TGTMSNNO.ENG = E
   For TGTMSNNO.TYPE, determine if TGTEFF has been specified. If not, TGTEFF = .10 (default)
   For TGTMSNNO.ENG = V
   For TGTMSNNO.TYPE, determine if TGTSVF has been specified. If not, TGTSVF = 1 (default)

2. Access the Attack Methods Table with the target type, size, method of engagement, ammunition priorities and target effects or SVF. Determine the amount of each type priority ammunition that should be fired.

   For TGTMSNNO.TYPE,.SIZE, .ENG,.AMMO1,.AMMO2, and TGTEFF or TGTSVF, access the Attack Method Table
   NUMVOL1 =
   NUMVOL2 =

3. Go to subroutine .FU

Subroutine TTFC.FIREMISSION.FASCAM

1. For ammunition specified FASCAMx, where x is the type FASCAM, determine if the requestor is authorized to employ that level of FASCAM. If not, end

   For TGTMSNNO.AMMO = FASCAMx,
   If TGTMSNNO.COORD NE FASCAMx.COORD, endto

2. Access the FASCAM Table to determine the number and type of volleys to fire

3. Go to subroutine .FU

Subroutine TTFC.FIREMISSION.FU

1. Access the AFU Table for each fire unit to determine which units are available. For available units, determine if they have the required amount of either type ammunition. For nonavailable units, put NO in the .FU.N column of the battalion mission file

   For fire unit 1-n,

   If PLTFIRE = YES and (BTRY.AMMO1 >.NUMVOL1 x 8 or BTRY.AMMO2 >.NUMVOL2 x 8), the fire unit is available

2. Determine the range to target for each available fire unit. If the range is greater than the battery maximum range, the fire unit is not available. Augment the mission out of range counter in the appropriate AFU file

For unit 1-n, FU.NRG =
If FU.NRG < MAX RG, OUTOFRG= OUTOFRG + 1
Next n

3. If the target is part of a schedule, go to subroutine .PREFP

If TGTMSNNO.CTL = SCHED, go to subroutine .PREFP

4. For available fire units, access the AFU file to determine the priority of assignment

FIREUNIT.N.PRI = FIREUNIT.N MISSIONS

5. For the available fire units, determine the units to fire beginning with priority 1-n

(a) Can FU 1-n perform the mission alone with either ammunition type

(b) Can any combination of two fire units perform the mission with either type ammunition

(c) Can the battalion perform the mission with either type ammunition

(d) When the answer to a-c is yes, indicate YES in the TGTMSNNO. FU column of the selected units. Annotate the nonselected units NS.

6. Determine the number of volleys for each fire unit and if this required volume of fire exceeds user input data for the maximum volleys volleys for any target

   NUMVOL FU.N = .AMMO.NVOLLEY / NUM FU
   If NUMVOL FU.N > MAXVOL, NUMVOL FU.N = MAXVOL

7. If no combination of the battalion's assets is acceptable, submit a request for fire to DivArty and end the mission in the fire unit and battalion queues

8. Go to subroutine .XMIT

Subroutine TTFC.FIREMISSION.XMIT

1. Determine the time required to conduct tactical and technical fire direction, FDTIME. Time is modeled as a normal distribution.

   If TGTMSNNO.CTL = IMMED, FDTIME = 5 seconds
   Draw a random number
   Compute FDTIME based on the random number, FDTIME.MEAN and FDTIME.SD

2. Determine the time to schedule transmission of the mission to the appropriate agencies

   TGTMSNNO.XMIT = TGTMSNNO.DTG + FDTIME

3. If the target is part of a schedule, schedule transmission through the COMMUNICATIONS MODULE to ROUTINE NNFP.PREFP at .XMIT

   If TGTMSNNO.CTL = NNFPn, go to ROUTINE
   NNFP.PREFP

4. If the target coordination has resulted in the mission being cancelled, schedule transmission of an end of mission to t..e originating agency

   If TGTMSNNO.COORD = EOM, TGTMSNNO.EFF= CTL,
   to ROUTINE FO.END

5. At the time of transmission, send the mission through the COMMUNICATIONS MODULE to the appropriate routine and decrement the battalion mission counter

   MSNCTR = MSNCTR-1

6. Determine if the battalion has the capability to process any more missions. If so, pop the highest priority mission and go to subroutine .ATTACK. If not, END

   If MSNCTR < MSNMAX, pop the queue and go to
   subroutine.ATTACK
   Else END

Subroutine TTFC.FIREMISSION.PREFP

1. For available fire units, determine which units can successfully engage the target and annotate the NNFP Fire Plan Table. A yes answer in any category ends this step and goes to the next step

   For fire unit 1-n:
   1.Can any unit perform the mission alone
   2.Can any two units perform the mission
   3.Can the battalion perform the mission
   If the answer is still no, delete this target and process the next target

2. For the minimum size unit(s) capable of firing, compute the time required to accomplish the mission

   FIRETIME = <(NUMVOL / NO FU) / (SUSTRATE)> + 1 min

3. Go to subroutine .XMIT

Subroutine TTFC.FIREMISSION.MFR

1. If the target effect is NOFIRE, set the fire unit status in the battalion file to no for the target, augment the time wasted counter in the appropriate unit AFU file and go to subroutine .FU to determine a new method of attack

   If TGTMSNNO.EFF = NOFIRE, the FU is not available, MSNTIME = current DTG-TGTMSNNO.DTG
   For battery AFU file,
   TIMEWASTED = TIMEWASTED+MSNTIME

.AMMOnVOLLEY = FU NUMVOL.N

Go to subroutine .FU

2. If the method of control is end of mission, augment the battalion mission fired counter and determine the average mission time

   If TGTMSNNO.CTL = EOM,

   TOTBNMSNFIRE = TOTBNMSNFIRE + 1

   BNMSNTIME = current DTG - TGTMSNNO.DTG

   TOTBNMSNTIME = TOTBNMSNTIME + BNMSNTIME

   AVEBNMSNTIME = TOTBNMSNTIME / TOTBNMSNFIRE

3. Change the target DTG to the current time and go to ROUTINE ATI.MFR

B. BATTERY FIRING SUBMODULE PROGRAM LOGIC

ROUTINE BTRY.FIRE

Purpose

To model the actions of the fire unit upon receipt of a fire mission

Logic

1. For an end of mission, go to subroutine .EOM

   If TGTMSNNO.CTL = EOM, go to subroutine .EOM

2. For a final protective fire, stop all current missions and process the FPF through subroutine .FFE

   If TGTMSNNO .CTL = FPF, queue all missions and go to subroutine .FFE

3. For an immediate suppression mission, stop all current missions except FPF's and fire the immediate suppression

4. If the mission is a correction on an ongoing mission, go to the appropriate subroutine

   If TGTMSNNO = nnnnCORR, go to subroutine .ADJ
   If TGTMSNNO = nnnnFFE, go to subroutine .FFE

5. Queue the mission in the fire unit mission queue in accordance with its priority. Assign the current time as the TGTMSNNO .TIME and augment the unit mission counter

6. Determine if a fire unit is idle. If so, pop the highest priority mission in the queue and determine if the mission requires revalidation based on its age. If so, change the method of control to check and output to subroutine .EOM

   If current time - TGTMSNNO .TIME > BTRYTIME,
   TGTMSNNO.CTL = CHECK, go to subroutine .EOM

7. Determine the method of control and flag the appropriate platoons for firing

   If TGTMSNNO .CTL = ADJ, set one unit status
   counter to YES. If .CTL = FFE, set both unit
   mission counters to YES

8. Access the AFU table to determine if at least one fire unit is capable of firing the mission. The unit must be in position, not in conflict and have the required ammunition

   If .CTL = .ADJ, RQDAMMO = NUMHOW*VOLLEY.N + 3
   If .CTL = .FFE, RQDAMMO = NUMHOW*VOLLEY.N

   If PLTFIRE = YES and RQDAMMO < AFU.AMMO.NOTY,
   the unit is capable

   If no units are capable, TGTMSNNO .EFF = NOFIRE,
   go to ROUTINE TTFC.FIREMISSION

9. For the capable unit(s) with platoon mission status of yes, determine the appropriate subroutine to process the mission

   If TGTMSNNO .CTL = ADJ, go to subroutine .ADJ
   If TGTMSNNO .CTL = FFE, go to subroutine .FFE

Subroutine BTRY.FIRE.ADJ

NOTE: THE AMMUNITION FOR ADJUSTMENT IS HE

1. Determine the technical fire direction time. Time is modeled as a normal distribution.

   Draw a random number
   Compute TFD based on the random number, TFD.MEAN and TFD.SD

2. Determine the reaction time on the howitzer and the time when ready to fire. Time is modeled as a normal distribution.

   Draw a random number
   Compute HRT based on the random number, HRT.MEAN and HRT.SD

   TGTMSNNO .TIME = current time + TFD + HRT

3. Determine the location of the impact of the round based on the range and error equations. The factor of 17.778 is a conversion factor from degrees to mils to take advantage of the relationship that 1 mil subtends 1 meter at a range of 1000 meters.

   For FU.NRG, CHG = ?
   For CHG, ERRRG = , ERRDF =

   ***For an explanation of the methodology for charge selection and error determination, see Chapter 6.

```
dx = tgtlocx - gunlocx
dy = tgtlocy - gunlocy
angle = arctan (dy/dx) * (17.778)
angleerror = ERRDF/FU.NRG
ang = angle + angleerror

IMPACTLOCy = (FU.NRG + ERRRG)*sin(ang)
IMPACTLOCx = (FU.NRG + ERRRG)*cos(ang)
```

4. If the method of control is at my command (.AMC), schedule the transmission of a unit ready flag to ROUTINE FO.FIREMISSION for the TGTMSNNO .FSCOORD. If the control is not specified, schedule the transfer of control to Routine BTRYSHOOT

Subroutine BTRY.FIRE.FFE

1. Determine the unit status. If the target is a FPF, queue any ongoing missions in the unit queue and process the FPF. For other missions, queue the incoming mission behind existing ones.

2. For each howitzer and each volley, determine the reaction time and the time to schedule each volley. If the mission is "at my command " or "time on target," the time when ready is the time of the last howitzer. If the unit is not ready by TOT + 5, the method of control becomes AMC. If no control is specified, howitzers will be scheduled to fire individually, when ready

   If TGTMSNNO .CTL = TOT, .FIRE = current time

+ HRTMAX

If .FIRE > TOTTIME + 5, TGTMSNNO .CTL = AMC

Else .FIRE = current time + HRTMAX

3. Determine the location of the impact of each round of each volley based on range and the error equations

For FU.NRG, CHG = ?

For CHG, ERRRG = , ERRDF =

***For an explanation of the methodology for charge selection and error determination, see Chapter 6.

dx = tgtlocx - gunlocx
dy = tgtlocy - gunlocy
angle = arctan (dy/dx) * (17.778)
angleerror = ERRDF/FU.NRG
ang = angle + angleerror

IMPACTLOCy = (FU.NRG + ERRRG)*sin(ang)
IMPACTLOCx = (FU.NRG + ERRRG)*cos(ang)

4. If the method of control is AMC, schedule the transmission of a battery ready flag to the ROUTINE FO. FIREMISSION or FSO.ALLOC.AIR for the TGTMSNNO .FSCOORD. For other methods, schedule the transfer of control to Routine BTRYSHOOT

Subroutine BTRY.FIRE.EOM

1. If TGTMSNNO .CTL = EOM, for units with this mission in their active queue, change the unit status to NO.

Decrement the unit mission counter. Determine if the unit has any missions in its queue.

(a) If yes, change the unit status to yes and pop the next mission in the queue. Go to the subroutine that corresponds to the method of control (.ADJ or .FFE)

(b) Send the end of mission data to ROUTINE TTFC.FIREMISSION

2. If TGTMSNNO .CTL = CHECK, set .COORD = NO, and schedule transmission of the data to ROUTINE FO.FIRE MISSION for TGTMSNNO .FSCOORD. Requeue the mission and pop the next highest priority mission. Return.

ROUTINE BTRY.SHOOT

Purpose

To model the actions at the firing unit at the time of firing.

Logic

NOTE: THIS ROUTINE IS CALLED FROM THE SCHEDULER

1. Access the AFU Table for the fire unit and determine if the unit is still capable of firing. If not, change the target effects indicator to no and go to ROUTINE TTFC.MFR

If PLTFIRE = YES, continue. Else TGTMSNNO.EFF = NOFIRE and go to ROUTINE TTFC.MFR

2. Determine the time of impact

IMPACTTIME = TGTMSNNO .FIRE + .TOF

3. At the time of firing:

(a) Send the TGTMSNNO .LOC,.IMPACT and TGTMSNNO.EFF = SHOT to the appropriate ROUTINE FO.FIREMISSION for the FO designated as the TGTMSNNO.FSCOORD

(b) Send the impact location, time and the ammunition data to the BDA MODULE

(c) Send the sound and flash indicators and the trajectory indicator to the appropriate OPFOR modules

4. Augment the volley counter for the fire unit. Compute the ammunition expended. Output this data to ROUTINE AFU.AMMOUPDATE

NOVOLn = 1
For howitzers 1-n that fired, AMMO.NEXP = 1

5. END

TABLE 20

METHOD OF ATTACK TABLE

TARGET TYPE	TARGET SUBTYPES AND METHODS OF ATTACK						
	UNKNOWN	LIGHT	MEDIUM	HEAVY	MISSILE	APC	AT
ADA	X (E)	X (E)	X (E)	X (E)	X (E)		
ARMOR	X (E)	X (E)	X (E)	X (E)		X (E)	
ARTY	X (E)	X (E)	X (E)	X (E)	X (V)		
MORTAR	X (V)	X (V)	X (E)	X (V)			
ROCKET/ MISSILE	X (E)	X (E)	X (E)	X (E)			X (E)
VEH	X (E)	X (E)	X (E)	X (E)			X (E)
GUN	X (V)	X (V)	X (V)	X (V)			X (V)
ASSEMBLY AREA	X (E)	TRP (E)	TRP/VEH (E)	MECH (E)	ARMOR (E)		
BUILDING	X (V)	ALL (V)					
BRIDGE	X (V)	FOOT (V)	PONTOON (V)	OTHER (V)			
CENTER	X (E)	SMALL (E)	BN & UP (E)				

TABLE 20
METHOD OF ATTACK TABLE (continued)

TARGET TYPE	TARGET SUBTYPES AND METHODS OF ATTACK				
	UNKNOWN	LIGHT	MEDIUM	HEAVY	MISSILE
PERSONNEL	X (V)	INF (V)	OP (V)	PTL (V)	
SUPPLY	X (V)	AMMO (V)	OTHER (V)		
TERRAIN	X (V)	ROAD (V)	JUNCT (V)	HILL (V)	OTHER (V)

NOTES:
1. Effects = (E), Volley = (V)
2. Volley targets may be specified effects in the input
3. Effects targets cannot be specified volley

TABLE 21

AMMUNITION PRIORITY TABLE

Ammunition must be selected down this list in priority

1. Commander's criteria
2. For TGTMSNNO.

TYPE	.ACT	.SUBTYPE	.SIZE	use block
CP	ALL	ALL	ALL	1
MSL/RKT	ALL	ALL	ALL	2
FA	ALL	ALL	ALL	3
ALL	WOODS	VEH, ARTY APC	ALL	4a
ADA, OP RADAR	 MOVING	 ALL	ALL ALL	4a 5
ALL	ALL	not ARM APC, ARTY PERS	ALL	6a
		VEH, CP ENGR, SVC RADAR	ALL	6b
ALL	ALL	ARM, APC ARTY	$4<x<18$	7
			$1<x<4$	8
			$x=1$	9
ALL	ALL	ALL	ALL	10

NOTE: This portion of the table is entered with the TGTMSNNO.TYPE. For the .TYPE, .ACT, .SUBTYPE and .SIZE, select the ammunition block to use in the second portion of the table.

TABLE 21
AMMUNITION PRIORITY TABLE (continued)

BLOCKS FROM WHICH TO SELECT AMMUNITION:

BLOCK	MLRS			8"			155mm			
	TGW	DPICM	SADARM	DPICM	HE	RAP	CUHD	DPICM	HE	RAP
1		c	b	d	f		a	e	g	
2	a	b		c	e			d	f	
3		b	a		e		c	d	f	
4a		e		a	c	f		b	d	g
4b		e		c	a	f		d	b	g
5							a			
6a		c		a	d	f		b	e	g
6b		a		b	d	f		c	e	g
7	a	d	c	e	g	i	b	f	h	j
8				b	d	f	a	c	e	g
9				a	c	e		b	d	f
10							a			

NOTES:

(1) This portion of the table is entered with the block number determined from the first portion of the table. Ammunition and weapon system type(s) are selected in priority a-j based on the type systems available and their ammunition status.

(2) This table was adapted from a gunnery handout for the Field Artillery Officers Advanced Course

TABLE 22

TTFC USER INPUT

Variable	Value	Explanation
FDTIME. MEAN	Time in seconds	The mean time to compute tactical fire direction for a mission
FDTIME. SD	Time in seconds	The standard deviation of the time to compute tactical fire direction for a mission
MSNMAX	1-n	The maximum number of missions that the battalion can process simultaneously
MAXVOL	1-n	The maximum number of volleys that a fire unit can shoot on one mission
FASCAMx	UNIT NO	The unit number of the FSCOORD authorized to request employment of FASCAM
FOR TGTMSNNOTYPE 1-n:		
.AMMO1	1-n	Ammunition to be fired against a specific type target
TGTEFF	.01-.99	The desired percentage effects on a given type target. Default is .10.
TGTSVF	1-n	The standard volley factor to be applied on a given type volley target. Default is 1.

TABLE 23

BTRYFIRE USER INPUT

Variable	Value	Explanation
TFDMEAN	Time in seconds	The mean time to compute technical fire direction on a correction
TFDSD	Time in seconds	The standard deviation of the time to compute technical fire direction on a correction
HRTMEAN	Time in seconds	The mean time to prepare the howitzer for firing
HRTSD	Time in seconds	The standard deviation of the time to prepare the howitzer for firing
BTRYTIME	Time in seconds	The maximum time that a mission can be active before it requires validation

APPENDIX G
INTERNAL DATABASE ROUTINES

A. BATTALION SUPPORT SUBMODULE LOGIC

ROUTINE SPRT.COORD

Purpose

To determine if a mission requires coordination or to determine the appropriate fire support agency to which intelligence data should be forwarded.

Logic

1. Access module target file to determine TGTMSNNO.LOC and .FSCOORD

2. Determine the zone of responsibility for the target's geometric location

   For TGTMSNNO.LOC, ZOR.SECTOR= n and HQZOR.SECTOR = o

3. Determine the fire support coordinator for the zone of responsibility

   If TGTMSNNO.CTL = INTEL
    For HQZOR.SECTOR, ZOR.FSCOORD = 1
    Go to Routine FSO.INTEL
   Else ZOR.SECTOR, ZOR.FSCOORD = m

4. Determine if the requestor is the zone's FSCOORD

If ZOR.FSCOORD=TGTMSNNO.FSCOORD, set TGTMSNNO.
COORD flag to YES
END

5. If the mission is not coordinated per (4) above, output the target number to ROUTINE FO.COORD for the appropriate zone's FSCOORD

<u>ROUTINE SPRT.PREFP</u>

<u>Purpose</u>

To determine the geometric sector to be used by the ATI in its search for targets to be incorporated to a schedule of fire

<u>Logic</u>

1. Determine the geometric zone of responsibility for the unit requesting the schedule of fires

   For UNITNO., determine ATI.ZOR1

2. Determine the next higher headquarters for the unit requesting the schedule and its geometric zone of responsibility

   For HQ, determine ATI.ZOR2

3. Output ATI.ZOR1 and ATI.ZOR2 to ROUTINE ATI.PREFP

B. ARTILLERY FIRE UNIT SUBMODULE LOGIC

ROUTINE AFU.AMMOUPDATE

Purpose

To update ammunition status after firing or battle damage, and to conduct internal ammunition resupply

Logic

1. If the input reflects a loss of ammunition, subtract the ammunition from the ammunition carrier (AC), if possible, then the howitzer. If the rounds are off the howitzer, initiate internal resupply

    For AC 1-n, if AMMO.NEXP < AMMO.N AC
     AMMO.N AC = AMMO.N AC - AMMO.NEXP
    ELSE AMMO.N HOW = AMMO.N HOW - AMM.NEXP, go to
     subroutine AFU.AMMOUPDATE.RES

2. If the input reflects rounds fired, update the position data and compute the current rate of fire. If the rate of fire exceeds the maximum for the weapon type, place the unit in a nonfiring status and compute the time required for the tubes to cool

    RDSEXP = RDSEXP + AMMO.NEXP
    RSR = RSR + AMMO.NEXP
    TSR = current time - resupply time
    NUMVOL = NUMVOL + NOVOL.N
    TIP = current time - occupation time
    RATE = RDSEXP / TIP

    If RATE > SUSTRATE, set PLTFIRE = no and compute
      the time when available:
       TIME = (RDSEXP / SUSTRATE) - TIP
       NEWTIME = TIME + current time

3. Update the fire unit firing status flag.

If IPRF = yes and NOCONFLICT = yes, PLTFIRE = yes
ELSE PLTFIRE = no

4. Compute the ammunition expenditure rate for all types of ammunition reflected in the input and normalize the rate to 24 hours. If this value exceeds the ASR/CSR, output the data to the LOGISTICS MODULE

For AMMO.N,
If ((RSR / TSR) x 24 hours / .NUMHCW) > ASR/CSR, output AMMO.N to LOGISTICS MODULE

5. Check each threshold value to determine if any value has been exceeded. If so, set the fire unit status to the threshold value and go to ROUTINE BTRYTAC.DEC

For exceeded threshold, PLT.NSTATUS = THRESHOLD.N

Subroutine AFU.AMMOUPDATE.RES

NOTE: THIS SUBROUTINE IS DESIGNED TO CONDUCT INTERNAL BATTERY RESUPPLY. WHEN THE CARRIER DOES NOT SUPPORT THE HOWITZER OR RESUPPLY IS RECEIVED FROM EXTERNAL SOURCES, ROUNDS ARE TRANSFERRED FROM THE AMMUNITION SECTION VEHICLES.

1. For howitzer 1-n, and ammunition type 1-n, resupply the howitzer from the ammunition

section vehicles (AMMO 1-Y) up to basic load. Determine the time required to accomplish the resupply and schedule the changeover of ammunition. Time is modeled using a normal distribution.

Draw a random number
Compute TIMEAMMO based on the random number, TIMEAMMO.MEAN and TIMEAMMO.SD

2. Repeat step one for each ammunition carrier

3. For ammunition vehicles, AMMO 1-Y, determine whether any vehicle(s) can be emptied by consolidating ammunition. If so, determine the time to accomplish the transfer and schedule the changeover. Time is modelled using a normal distribution.

Draw a random number
Compute TIMEAMMO based on the random number, TIMEAMMO.MEAN and TIMEAMMO.SD

4. For ammunition section vehicles, AMMO 1-Y, determine if any vehicle is empty and, if so, place the vehicle on the Movement MODULE enroute to resupply.

5. If the ammunition resupply vehicles are external to the battery, set the time since resupply (TSR) and the rounds since resupply (RSR) to zero

6. Return to the main routine

ROUTINE AFU.UPDATE

Purpose

To update counters in the AFU file as warranted

Logic

1. For a change in the position or conflict status of a fire unit, change the status as indicated and determine the new platoon fire status

   If IPRF = yes and NOCONFLICT = yes,
   PLTFIRE = YES,
   ELSE PLTFIRE = NO

2. If IPRF = move, set the number of volleys from position, augment the battalion time in position, missions out of range, percent of range past FLOT and FLOT distance to zero. Set IPRF AND PLTFIRE flags to no and go to ROUTINE AFU.AMMOUPDATE

   BNTIP = BNTIP + TIP

3. For IPRF = occupied, begin tracking the counters set to zero in step 2.

ROUTINE AFU.RECONSTITUTE

Purpose

To account for battle losses and reconstitute the surviving forces into viable units

Logic

1. Subtract all losses from the appropriate counters

2. Determine the howitzer status. If a howitzer is NOTOP.BDA, place the personnel into the cannoneer pool and the remaining ammunition into the ammunition pool. If the howitzer is operational but personnel count is less than the minimum manning requirement (MINMAN), the howitzer is NOTOP.MAN

3. Determine the status of the ammunition carriers as in step 1

4. Determine the status of the FDC. If the vehicle or BOTH radios are not operational, the FDC is NOTOP.BDA and the personnel should be placed in the FDC pool. If the personnel count is less than the minimum requirement, (MINMANFDC), the FDC is NOTOP.MAN. If the FDC status is NOTOP.XXX, go to subroutine AFU.RECONSTITUTE.FDC

5. Reconstitute the howitzer sections which are not adequately manned by transferring personnel first from the 13B pool then from

another section which is above the minimum manning level. For howitzers which cannot be reconstituted, transfer the personnel and ammunition to the appropriate pool.

For howitzer NOTOP.MAN, determine the required NUMMAN

If the 13B pool > NUMMAN, transfer the personnel, change the howitzer status to OP

If the 13B pool < NUMMAN, transfer the personnel and determine the new NUMMAN. For howitzers, EXCESS = NUMMANOH - MINMAN. If EXCESS > NUMMAN , transfer the personnel and change the howitzer status to OP.

ELSE place all personnel and ammunition into the pool

6. For ammunition carriers with status NOTOP.MAN, repeat the step above

7. For all howitzers that are operational, in two passes fill the ammunition status from the pool, first to minimum basic load level then to full capacity

8. For ammunition carriers that are operational, repeat the step above

9. Determine the number of howitzers remaining in the BATTERY. If less than three, the entire

unit is ineffective and the PLT.NSTATUS for both platoons should be BTRYINEFF. If less than six, the smallest platoon is ineffective. Consolidate the assets into one platoon (may be larger than normal).

10. Determine the number of howitzers in the platoon. If less than or equal to two, transfer a howitzer from the other platoon

11. Go to subroutine AFU.RECONST.FDC

Subroutine AFU.RECONST.FDC

1. Determine the number of FDC's required. If the battery is ineffective, none are required, go to ROUTINE BNTAC.RECONST. The number required is equal to the number of platoons with status not equal to ineffective

2. If the number of effective FDC's is greater than or equal to the number of FDC's required, go to subroutine AFU.RECONST.RPT

3. If the FDC is NOTOP.BDA and the reason is radios, determine whether the other FDC can transfer a radio. If not, the FDC remains NOTOP.BDA, go to subroutine AFU.RECONST.RPT

4. If the FDC IS NOTOP.MAN, determine if the other FDC can transfer personnel. If not, the FDC remains NOTOP.MAN. Go to AFU.RECONST.RPT

   If (NUMMAN.FDC1+ NUMMAN.FDC2) / .MINMAN.FDC > 2, transfer personnel to create two operational FDC's

Subroutine AFU.RECONST.RPT

1. Determine the time required to reconstitute the force and schedule the changes. Time is modeled using a normal distribution.

   Draw a random number
   Compute RECONSTTIME based on the random number, RECONSTTIME.MEAN and RECONSTTIME.SD

2. At reconstitution time, for platoons whose status are not ineffective, change the IPRF and NOCONFLICT counter to yes. Determine the PLTFIRE status

3. Go to ROUTINE AFU.BNRECONST

ROUTINE AFUBN.RECONST

Purpose

To allocate forces from battalion elements which have become ineffective and to determine the level of attrition of the battalion's forces

Logic

1. If the fire unit status is other than ineffective, change the status to update and go to ROUTINE BNTAC.THRESH

   If PLT.NSTATUS NOT = INEFF, PLT.N STATUS equals UPDATE. Go to ROUTINE BNTAC.THRESH

2. Determine the assets available from the ineffective unit and reallocate to the other fire units based on need:

   (a) Howitzers and prime movers are assigned to the fire unit with the least operational howitzers until full

   (b) FDC's are assigned to the unit with the least number of operational FDC's until full

   (c) Ammunition vehicles are assigned to the unit with the least total rounds until it reaches its basic load

   (d) Personnel are assigned by type to the unit with the lowest personnel to equipment ratio until at 100%

   (e) If all units reach 100%, the excess is assigned to the last element considered

3. Determine the minimum route from the current location of the equipment and personnel to the new unit of assignment and place the elements on the route in the MOVEMENT MODULE

4. Determine the total percent attrition of the battalion in terms of effective howitzers which are supported by an operational FDC

   ATT= 1-(EFFECTIVE HOWITZERS)/MAXHOW

5. Determine if the attrition exceeds the level established by the user and, if so, adjust the acceptable probabilities of detection

   If ATT > MAXATT, PROBMAX = PROBMAX2 and PROBMIN = PROBMIN2

6. Determine the average time between a unit's request to move and the realization of the threat

   NOATTK = NOATTK + 1
   AVEATTKTIME = (AVEATTKTIME+ ATTKTIME) / NOATTK

7. PLT.N STATUS = UPDATE, go to ROUTINE BNTAC.THRESH

TABLE 24

SPRT USER INPUT

Variable	Value	Explanation
For UNITNO 1-n	ARC no, ZOR#, FSCOORD#	For each unit, the input must reflect the geographic sector as represented on the network. The unit numbering must reflect the heirarchical organization, an associated zone number (ZOR#), and fire support officer number(FSCOORD#)

TABLE 25

AFU DATABASE REQUIREMENTS

The following data must be entered for each type howitzer, prime mover, ammunition carrier, fire direction center , radio and TACFIRE where applicable

Variable	Explanation
MTBF	The mean time between failure for a piece of equipment
MTTR	The mean time to repair a piece of equipment which has failed

TABLE 26

AFU USER INPUT

Variable	Values	Explanation
.MINMAN. .FDC .HOW .AC	1-n	The minimum number of personnel required to effectively man an entity. When below this, the equipment becomes nonoperational (.NOTOP. MAN)
TIMEAMMO. MEAN	Time in seconds	The mean time to tran- fer ammunition between two vehicles
TIMEAMMO. SD	Time in seconds	The standard deviation of the time to transfer ammunition between two vehicles
RECONST TIME.MEAN	Time in seconds	The mean time to recon- stitute a unit
RECONST TIME.SD	Time in seconds	The standard deviation of the time to reconsti- tute a unit
MAXATT	0-1.0	The attrition point, in percent, at which surviva- bility of the remaining force increases in impor- tance with respect to fire support.PROBMAX2 and PROBMIN2 become effective at this time.
PROBMIN2	0-1.0	The revised probability of detection which corre- sponds to PROBMIN at the MAXATT point. Must be < PROBMIN.
PROBMAX2	0-1.0	The revised probability of detection which corre- sponds to PROBMAX at the MAXATT point. Must be < PROBMAX.

TABLE 26
AFU USER INPUT (continued)

For ammunition type 1-n:

BTRYBL	1-n	The battery basic load of the ammunition
BTRYMIN	1-n	The level of ammunition which causes resupply to be initiated
HOWBL	1-n	The howitzer basic load of the ammunition
AC/PMBL	1-n	The ammunition carrier basic load
AMMOBL	1-n	The ammunition section vehicle basic load
CSR/ASR	1-n	The number of rounds per tube per day of the type ammunition available
SUSTRATE	1-n	The maximum rate of fire in rounds per minute. Firing ceases when this value is exceeded

APPENDIX H

ROUTINE FSO.ALLOCATE METHODOLOGY

A. CONDUCT OF THE SIMULATION

The enclosed computer simulation was conducted to ensure that the methodology for Routine FSO.ALLOCATE is feasible. The purpose of the routine is to simulate the decision process of the FSO with regard to selection of an asset to engage a given target which is in a certain status and is defended by specific ADA systems. The algorithm uses utility theory to determine the value of employing an asset against a target given its defenses. This utility represents the expected gain of employing the asset and is computed by determining the gain (expected gain minus expected loss) and multiplying this value by the probability that the asset is available to engage the target. The algorithm used in the program to determine the asset is:

E(GAIN) = (TVATGT*PKTGT) - (TVAASSET*PLOSS.ASSET)
U(X)=E(GAIN*Pr(AVAILABLE) where:

U(X) is the utility of employing the asset

E(GAIN) is the expected gain minus the expected loss

TVATGT is the target value

PKTGT is the probability that the asset can kill the target

TVAASSET is the value of the asset

PLOSS.ASSET is the probability that the asset will be killed while engaging the target

Pr(AVAILABLE) is the probability that the asset will be available to engage the target

The algorithm also allows the asset to be selected based on the risk status of the user.

The simulation was established with five target types i which were assigned an arbitrary designation and, based on this designation, an arbitrary value. The targets considered, and their value were:

Tank platoon (TKPLT)-300
BMP platoon (BMPPPLT)-250
ADA Site (ADASITE)-500
Infantry platoon (INFPLT)-50
Regimental HQ (REGTHQ)-2000

Four typical air defense system types k were designated to defend the targets. The probability of each of these systems to kill close air support aircraft and attack helicopters was determined. The ADA systems employed and the Pk matrix applied were:

	ASSET	
ADA	AH	CAS
SA8	.1566	.1166
SA9	.1200	.0900
ZSU	.1700	.1200
SA7	.0656	.0356

The four asset types j which are normally considered by an FSO were then assigned a value relative to those established for the targets and the probability of kill for each asset against each target was determined. The values assigned and the Pk matrix used were:

Field artillery (FA)-600
Mortar (MTR)-400
Close air support (CAS)-2000
Helicopter (AH)-1500

Probability of Kill

	TK	BMP	ADA	INF	REGT
FA	0.3	0.3	0.5	0.4	0.4
MTB	0.2	0.2	0.3	0.3	0.2
CAS	0.6	0.7	0.7	0.7	0.7
AH	0.6	0.6	0.6	0.6	0.6

Representative response times for the assets were determined and applied to the simulation as follows:

FA - 0.033 (2 min)
MCRTAB - 0.033 (2 min)
CAS, ON STATION - 0.0833 (5 min)
CAS,SCRAMBLE - 1.0 (1 hour)
AH, ON STATION - 0.0833 (5 min)
AH, SCRAMBLE - 0.5 (30 min)

At this time, the simulation was conducted for all possible i,j,k combinations at ranges of 5, 10 and 20 kilometers for target speeds of 0, 25 and 50 kilometers per hour.

B. OUTPUT FROM THE SIMULATION

1. General

The actual simulation was conducted for each target, at each range, at each speed. Table 8fsob gives a sample of the output for each target, at each range, and shows, across the row, the computed utility for employing each asset given that the target is defended by the ADA system shown in the left column.

The results of the simulation (Table 8fsct) demonstrated that the algorithm performed in a predictable manner. The selection criteria for a target resulted in selection of the asset that could best engage that target unless the threat to the best asset was prohibitive. At this point, the program selected the next best asset given the threat. Because the algorithm appears to make a logical selection for asset-target pairs based on the target, threat to the asset and range to target, the algorithm will be incorporated in Routine FSC.ALLOCATE.

2. Explanation of the Output

The first target listed in Table 6fsct is a stationary tank platoon at a range of 5000 meters. The utility of employing the assets listed as column headings is dependent on the target defense which is contained in the row headings. The column headings represent assets as shown:

FA - field artillery
MTR - mortars
CASOS - close air support aircraft which are on station
CASSCR - close air support aircraft which must be scrambled
AHCS - attack helicopters which are on station
AHSCR - attack helicopters which must be scrambled

The assets selected for engagement of the targets given each target defense are:

IF DEFENSE IS:	ASSET IS:	UTILITY IS:
SA8	FA	43.6
SA9	AHCS/AHSCR	45.0
ZSU	FA	43.6
SA7	AHCS/AHSCR	126.6

TABLE 27

ASSET VS. TARGET UTILITY

THE UTILITY OF EMPLOYING AN ASSET AGAINST A TKPLT
AT RANGE 5.0 KM MOVING AT A SPEED OF 0.1 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	43.6	29.1	0.0	0.0	5.1	5.1
SA9	43.6	29.1	0.0	0.0	45.0	45.0
ZSU	43.6	29.1	0.0	0.0	0.0	0.0
SA7	43.6	29.1	48.8	48.8	126.6	126.6

THE UTILITY OF EMPLOYING AN ASSET AGAINST A TKPLT
AT RANGE 10.0 KM MOVING AT A SPEED OF 25.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	43.6	0.0	0.0	0.0	0.0	0.0
SA9	43.6	0.0	0.0	-24.0	0.0	0.0
ZSU	43.6	0.0	0.0	0.0	0.0	0.0
SA7	43.6	0.0	48.8	19.5	19.8	15.6

THE UTILITY OF EMPLOYING AN ASSET AGAINST A TKPLT
AT RANGE 20.0 KM MOVING AT A SPEED OF 50.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	43.6	0.0	0.0	0.0	0.0	0.0
SA9	43.6	0.0	0.0	-24.0	0.0	0.0
ZSU	43.6	0.0	0.0	0.0	0.0	0.0
SA7	43.6	0.0	48.8	19.5	19.8	15.6

THE UTILITY OF EMPLOYING AN ASSET AGAINST A BMPPLT
AT RANGE 5.0 KM MOVING AT A SPEED OF 50.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	28.6	19.1	0.0	-13.8	-24.9	-5.0
SA9	28.6	19.1	0.0	-6.5	15.0	3.0
ZSU	28.6	19.1	0.0	-16.5	-30.0	-6.0
SA7	28.6	19.1	43.8	4.4	96.6	19.3

C. SIMULATION PROGRAM

```
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C     X                                              X
C     X          FSO.ALLOCATE                        X
C     X                                              X
C     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
C
C
C      ****** VARIABLE DEFINITIONS******
C
C      ASSET(I)-THE NAME OF THE ASSET TO BE EMPLOYED
C      TARGET(J)-THE NAME OF THE TARGET TO BE ENGAGED
C      ADA(M)-THE NAME OF ADA WEAPON DEFENDING TARGET
C      RG(R)-THE RANGE FROM THE FLOT TO THE TARGET
C      ASTTVA(I)-THE VALUE OF ASSET I
C      TGTTVA(J)-THE VALUE OF TARGET J
C      SPD(L)-THE SPEED,IN KM/HR, OF THE TARGET
C      PK(I,J)-PROBABILITY OF ASSET I KILLING TARGET J
C      ETR(I)-THE EXPECTED RESPONSE TIME OF ASSET I
C      ADAPK(I,M)-THE PROBABILITY THAT ADA WEAPON M
C                 KILL ASSET M
C      PLOSS(I)-THE PROBABILITY OF LOSING ASSET I WHEN
C               ENGAGING TARGET J
C      LOSS(I)-EXPECTED LOSS OF VALUE FROM EMPLOYING
C               ASSET I AGAINST TARGET J
C      GAIN(I)-EXPECTED GAIN OF VALUE FROM EMPLOYING
C               ASSET I AGAINST TARGET J
C      EGAIN(I)-THE TOTAL EXPECTED GAIN FROM EMPLOYING
C               ASSET I AGAINST TARGET J
C      TFLOT-TIME, IN HOURS, UNTIL TARGET IS EXPECTED
C            TO REACH THE FLOT
C      PRAVL(I)-THE PROBABILITY THAT ASSET I CAN ENGAGE
C              TARGET J BEFORE TARGET CAN REACH FLOT
```

TABLE 27
ASSET vs TARGET UTILITY (continued)

THE UTILITY OF EMPLOYING AN ASSET AGAINST A BMPPLT
AT RANGE 10.0 KM MOVING AT A SPEED OF 0.1 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	28.6	0.0	0.0	0.0	0.0	0.0
SA9	28.6	0.0	0.0	0.0	0.0	0.0
ZSU	28.6	0.0	0.0	0.0	0.0	0.0
SA7	28.6	0.0	43.8	43.8	-10.2	-10.2

THE UTILITY OF EMPLOYING AN ASSET AGAINST A BMPPLT
AT RANGE 20.0 KM MOVING AT A SPEED OF 25.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	28.6	0.0	0.0	0.0	0.0	0.0
SA9	28.6	0.0	0.0	0.0	0.0	0.0
ZSU	28.6	0.0	0.0	0.0	0.0	0.0
SA7	28.6	0.0	43.8	35.0	-10.2	-10.2

THE UTILITY OF EMPLOYING AN ASSET AGAINST A ADASITE
AT RANGE 5.0 KM MOVING AT A SPEED OF 0.1 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	203.6	119.1	36.8	36.8	125.1	125.1
SA9	203.6	119.1	110.0	110.0	165.0	165.0
ZSU	203.6	119.1	10.0	10.0	120.0	120.0
SA7	203.6	119.1	218.8	218.8	246.6	246.6

THE UTILITY OF EMPLOYING AN ASSET AGAINST A ADASITE
AT RANGE 10.0 KM MOVING AT A SPEED OF 25.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	203.6	0.0	36.8	14.7	0.0	-39.8
SA9	203.6	0.0	110.0	44.0	0.0	24.0
ZSU	203.6	0.0	10.0	4.0	0.0	-48.0
SA7	203.6	0.0	218.8	87.5	139.8	108.8

TABLE 27
ASSET vs TARGET UTILITY (continued)

THE UTILITY OF EMPLOYING AN ASSET AGAINST A ADASITE
AT RANGE 20.0 KM MOVING AT A SPEED OF 50.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	203.6	0.0	36.8	14.7	0.0	-39.8
SA9	203.6	0.0	110.0	44.0	0.0	24.0
ZSU	203.6	0.0	10.0	4.0	0.0	-48.0
SA7	203.6	0.0	218.8	87.5	139.8	108.8

THE UTILITY OF EMPLOYING AN ASSET AGAINST A INFPLT
AT RANGE 5.0 KM MOVING AT A SPEED OF 0.1 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	-26.4	-15.9	0.0	0.0	0.0	0.0
SA9	-26.4	-15.9	0.0	0.0	0.0	0.0
ZSU	-26.4	-15.9	0.0	0.0	0.0	0.0
SA7	-26.4	-15.9	0.0	0.0	-23.4	-23.4

THE UTILITY OF EMPLOYING AN ASSET AGAINST A INFPLT
AT RANGE 10.0 KM MOVING AT A SPEED OF 25.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	-26.4	0.0	0.0	0.0	0.0	0.0
SA9	-26.4	0.0	0.0	0.0	0.0	0.0
ZSU	-26.4	0.0	0.0	0.0	0.0	0.0
SA7	-26.4	0.0	0.0	-38.5	0.0	0.0

THE UTILITY OF EMPLOYING AN ASSET AGAINST A INFPLT
AT RANGE 20.0 KM MOVING AT A SPEED OF 25.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	-26.4	0.0	0.0	0.0	0.0	0.0
SA9	-26.4	0.0	0.0	0.0	0.0	0.0
ZSU	-26.4	0.0	0.0	0.0	0.0	0.0
SA7	-26.4	0.0	0.0	0.0	0.0	0.0

```
C      U(I)-FINAL EXPECTED UTILITY OF EMPLOYING ASSET I
C              AGAINST TARGET J AND IS DETERMINED BY
C              MULTIPLYING THE E(GAIN) BY THE PRAVAIL
C
C      *******NOTE: THE DETERMINATION OF ADAPK WAS MADE
C             FROM VARIOUS SOURCES BASED ON SYSTEM
C             SYSTEM EFFECTIVENESS WHICH INCLUDED
C             PR(DETECT) AND PR(KILL). THIS VALUE WAS
C             THEN REDUCED BY ESTIMATED EFFECTIVENESS
C             OF COUNTERMEASURES.
C
C
C
C      ******VARIABLE DECLARATIONS******
       INTEGER ASST(6)
       REAL ASTTVA(6),TGTTVA(6),ETR(6),PK(6,5),MAX
       REAL PLOSS(6),LOSS(6),GAIN(6),EGAIN(6)
       REAL ADAPK(6,4),PDET(4),TFLOT(6),PRAVL(6),U(6)
       REAL RG(3),SPD(3),AB(6),BA(6),GLOSS(6)
       CHARACTER*7 ASSET(6),TARGET(5)
       CHARACTER*7 ADA(4),BEST
C
C
C      ******READ INPUT******
       READ,(ASST(I),I=1,6)
       READ,(ASSET(I),I=1,6)
       READ,(TARGET(J),J=1,5)
       READ,(ADA(M),M=1,4)
       READ,(RG(K),K=1,3)
       READ,(ASTTVA(I),I=1,6)
       READ,(TGTTVA(J),J=1,5)
       READ,(SPD(L),L=1,3)
       DO 1 I=1,6
           READ,(PK(I,J),J=1,5)
1      CONTINUE
```

TABLE 27
ASSET vs TARGET UTILITY (continued)

THE UTILITY OF EMPLOYING AN ASSET AGAINST A REGTHQ
AT RANGE 5.0 KM MOVING AT A SPEED OF 0.1 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	753.6	369.1	1086.8	1086.8	1025.1	1025.1
SA9	753.6	369.1	1160.0	1160.0	1065.0	1065.0
ZSU	753.6	369.1	1060.0	1060.0	1020.0	1020.0
SA7	753.6	369.1	1268.8	1268.8	1146.6	1146.6

THE UTILITY OF EMPLOYING AN ASSET AGAINST A REGTHQ
AT RANGE 10.0 KM MOVING AT A SPEED OF 50.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	753.6	0.0	1086.8	217.4	675.3	340.1
SA9	753.6	0.0	1160.0	232.0	795.0	372.0
ZSU	753.6	0.0	1060.0	212.0	660.0	336.0
SA7	753.6	0.0	1268.8	253.8	1039.8	437.3

THE UTILITY OF EMPLOYING AN ASSET AGAINST A REGTHQ
AT RANGE 20.0 KM MOVING AT A SPEED OF 25.0 KPH

DEFENDER	FA	MTR	CASOS	CASSC	AHOS	AHSC
SA8	753.6	0.0	1086.8	869.4	675.3	650.2
SA9	753.6	0.0	1160.0	928.0	795.0	730.0
ZSU	753.6	0.0	1060.0	848.0	660.0	640.0
SA7	753.6	0.0	1268.8	1015.0	1039.8	1019.2

```
      READ, (ETR(I),I=1,6)
      DO 2 I=1,6
         READ, (ADAPK(I,M),M=1,4)
2     CONTINUE
      READ, (AB(I),I=1,6)
      READ, (BA(I),I=1,6)
C
C     ******DETERMINE THE E(GAIN) OF EACH COMBINATION*
C
C     ******FOR EACH TARGET******
      DO 3 J=1,5
C
C     ******AT EACH RANGE FROM THE FLOT******
      DO 4 K=1,3
C
C     ******FOR TARGET SPEED******
      DO 5 L=1,3
C
C     ******PRINT THE MATRIX HEADER*****
            PRINT 200,TARGET(J)
            PRINT 201,RG(K),SPD(L)
         PRINT 601,ASSET(1),ASSET(2),ASSET(3),ASSET(4),
C       XASSET(5),ASSET(6)
         PRINT 603
C
C     ******DEFENDED BY******
      DO 6 M=1,4
C
C     ******DETERMINE THE GAIN OF EACH ASSET******
C
C     ***************INDIRECT FIRE***
      DO 7 I=1,6
            PLOSS(I)=(1-EXP(-(0.0402)*2))*AB(I)
            PLOSS(I)=PLOSS(I)*ASTTVA(I)
C
```

```
C       ***************AIR ASSETS***
             GLOSS(I)=ADAPK(I,M)*ASTTVA(I)*BA(I)
C
C        ********FOR AH OPERATING BEYOND FLOT******
        IF (RG(K).GT.5) THEN
          IF (ASST(I).EQ.5) THEN
             GLOSS(I)=3*GLOSS(I)
          ELSEIF (ASST(I).EQ.6) THEN
             GLOSS(I)=2*GLOSS(I)
          END IF
        END IF
C
C        *********DETERMINE WHICH VALUE OF LOSS TO USE
             IF (GLOSS(I).LE.0) THEN
                LOSS(I)=PLOSS(I)
             ELSE
                LOSS(I)=GLOSS(I)
             END IF
             GAIN(I)=TGTTVA(J)*PK(I,J)
             EGAIN(I)=GAIN(I)-LOSS(I)
C
C        ***DETERMINE THE UTILITY OF USING EACH ASSET**
             TFLOT(I)=RG(K)/SPD(L)
             PRAVL(I)=TFLOT(I)/ETR(I)
             IF (PRAVL(I).GT.1.0) THEN
               PRAVL(I)=1.0
             END IF
             U(I)=EGAIN(I)*PRAVL(I)
             IF (U(I).LE.-50.0) THEN
                 U(I)=0
             END IF
C         ************PAST MORTAR MAX RANGE******
        IF (RG(K).GT.7) THEN
          IF (ASST(I).EQ.2) THEN
             U(I)=0
```

```
          END IF
         END IF
C
C
7       CONTINUE
C       ******PRINT THE MATRIX*******
          PRINT 602,ADA(M),U(1),U(2),U(3),U(4),U(5),
         XU(6)
          PRINT 603
C
6       CONTINUE
C
5       CONTINUE
C
4       CONTINUE
C
3       CONTINUE
C
200     FORMAT('-',' THE UTILITY OF EMPLOYING AN ASSET
       XAGAINST A',2X,A10)
201     FORMAT(T1,' AT RANGE',2X,F4.1,2X,'KM MOVING AT
       XA SPEED OF',2X,XF6.1,2X,'KPH')
601      FORMAT(T3,'0','DEFENDER',3X,A6,1X,A6,1X,A6,1X,
        XA6,1X,A6,1X,A6)
602      FORMAT(T4,A7,1X,F6.1,1X,F6.1,1X,F6.1,1X,F6.1,
        X1X,F6.1,1X,F6.1)
603      FORMAT('-------------------------------------
        X----------------')
        STOP
        END
```

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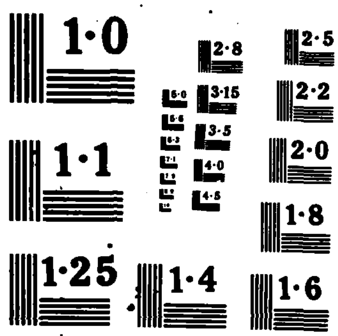

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117 Moran Circle
Monterey, California 93940

18. Mrs. Bea Stone Green 1
410 Garden Avenue
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